CHEMICAL AND MECHANICAL FALLOW WEED CONTROL METHODS IN FLORIDA VEGETABLE CROPS

By

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To my Parents

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TABLE OF CONTENTS

page

ACKNOWLEDGMENTS 4

LIST OF FIGURES 11

ABSTRACT....19

CHAPTER

1 LITERATURE REVIEW 21

Introduction....21
Fallowing and Fallow Weed Control 21
Reasons for Fallowing....21
Weeds: Explanations and Problems 22
Sexual and Asexual Reproduction....23
Characteristics of Weeds 23
Crop-Weed Competition 25
Critical Weed-Free Period....26
Host plants for pests 27
Common and Troublesome Weeds in Vegetable Crops....28
Cyperus rotundus L. 28
Eleusine indica (L.) Gaertn. 30
Portulaca oleracea L. 30
Digitaria sanguinalis (L.) Scop. 30
Amaranthus hybridus 31
Cyperus esculentus L. 31
Negative Impact of Weeds in Various Crops....31
Methyl Bromide Alternatives....33
Tillage....38
Seed Bank (Survival and Dormancy)....39
Stale Seed Bed....40
Herbicides Labeled for Fallowing -Post Emergence Applications 41
Halosulfuron-methyl 41
Glyphosate....44
Paraquat....48
Trifloxysulfuron 49
Pre-emergence Herbicides....51
EPTC 51
Halosulfuron-methyl 53
Pre-plant herbicides labeled for vegetable crops....54
S-metolachlor 54
Clomazone....56
Pendimethalin....57

Oxyfluorfen 58
General factors effecting herbicide efficacy....60
Herbicide activity on crops....62
Previous fallow work....62

2 FALLOW EXPERIMENT - LIVE OAK, FL LOCATION 66

Materials and Methods 66
Year 1 - Fallow....67
Year 1 - Crop....67
Year 2 - Fallow....69
Year 2 - Crop....71
Statistical Analysis 73
Results and Discussion 73
Fallow Period....73
Purple nutsedge fallow 73
Yellow nutsedge....75
Florida pusley fallow....75
Crabgrass fallow....76
Hairy indigo fallow 78
Browntop millet fallow 78
Smallflower morningglory (data not shown) 79
Carpetweed fallow....80
Redweed fallow (data not shown)....80
Other minor weeds (data not shown) 81
Crop Data....81
Purple nutsedge in peppers - year 1 81
Weeds in pepper rows - year 1 82
Weeds in pepper row middle - year 1 83
Pepper heights - year 1....84
Weeds in beans - year 1....84
Crop yields - year 1 (data not shown) 87
Purple nutsedge within the pepper row - year 2....87
Cabbage weeds - year 2....89
Bean weeds - year 2 93
Pepper and bean dry weights - year 2 (data not shown)....96
Cabbage yield - year 2....97
Conclusions....98
Purple Nutsedge Control 98
Yellow Nutsedge Control....98
Florida Pusley Control....99
Large Crabgrass Control....100
Hairy Indigo Control 100
Browntop Millet Control 101
Smallflower Morningglory Control....101
Carpetweed Control....101
Cutleaf Evening Primrose Control 101

Cabbage Yield 102

3 FALLOW EXPERIMENT – CITRA, FL LOCATION 151

Objective 151
Materials and Methods 151
Fallow Measurements 152
Crop 1 153
Crop 2 153
Post Cabbage Harvest Weed Control 154
Statistical Analysis 154
Results and Discussion 154
Fallow Period (Sedges) 154
Effect of different fallow treatments on purple nutsedge control - year 1 154
Effect of different fallow treatments on purple nutsedge control - year 2 157
Purple nutsedge counts - year 2 159
Yellow fallow control ratings - year 2 159
Yellow nutsedge counts - year 2 160
Fallow Period - Grasses 160
Crabgrass fallow ratings - year 1 160
Crabgrass fallow ratings - year 2 161
Crabgrass counts - year 2 163
Goosegrass control ratings - year 2 165
Goosegrass counts - year 2 166
Corn fallow ratings - year 2 166
Crowfootgrass control ratings - year 2 166
Fallow - Broadleaves 167
Amaranth fallow control ratings - year 1 167
Amaranth fallow control ratings - year 2 168
Amaranth counts - year 2 169
Purslane fallow ratings - year 1 170
Purslane fallow ratings - year 2 172
Purslane counts - year 2 172
Florida pusley control ratings - year 1 173
Florida pusley control ratings - year 2 173
Florida pusley counts - year 2 174
Cutleaf evening primrose control ratings - year1 175
Cutleaf ground cherry control ratings - year 2 175
Cutleaf ground cherry counts - year 2 176
Carpetweed fallow control ratings - year 2 177
Carpetweed counts - year 2 177
Redweed control ratings - year 2 178
Cabbage Vigor Ratings and Weed Control Ratings during the Crop 178
Purple Nutsedge 178
Fallow treatment effect 178
Pre-plant treatment effect 180
Yellow Nutsedge Control in Cabbage 180

Crabgrass Control in Cabbage 181
Fallow treatment effect....181
Pre-plant treatment effect 182
Cutleaf Evening Primrose....182
Fallow treatment effect....182
Pre-plant treatment effect 183
Purslane Control in Cabbage 183
Fallow treatment effect....183
Pre-plant treatment effect 184
Cabbage Weed Counts 184
Cabbage Vigor....185
Cabbage Yield - Year 2 186
Cabbage Number....186
Total Cabbage Weight....187
Average Cabbage Weight....188
Total Cabbage Weight....189
Average Cabbage Weight....189
Weeds after Cabbage Harvest 190
Purple nutsedge post cabbage harvest....190
Crabgrass post cabbage harvest....191
Pusley post cabbage harvest....191
Purslane post cabbage harvest....192
Conclusions....193
Fallow Treatments....193
Untreated fallow....193
Cultivation....193
Glyphosate....194
Glyphosate plus s-metolachlor 194
Glyphosate plus trifloxysulfuron....195
Paraquat....196
Paraquat plus s-metolachlor 197
Paraquat plus trifloxysulfuron....197
Pre-plant Herbicide Treatments....198
Oxyfluorfen 198
S-metolachlor 198

4 CONCLUSIONS – LIVE OAK AND CITRA SUMMARY 268

Untreated Fallow Effect on Weeds....268
Live Oak 268
Citra 268
Effect of Fallow Cultivation on Weeds (Regardless of Herbicides) - Live Oak 269
Fallow Cultivation Effect on Weeds....269
Effect of Fallow Herbicides on Weeds (Regardless of Cultivation) - Live Oak 270
Fallow Herbicide Effects on Weeds 270
Effect of Fallow Treatments on Weeds within Peppers 272
Untreated Fallow Effect on Peppers - Live Oak 272

Fallow Cultivation Effect on Peppers - Live Oak 272
Effect of Fallow Herbicides on Bell Pepper (Regardless of Cultivation) - Live Oak ...273
Fallow Herbicide Effect on Peppers - Live Oak 273
Effects of Fallow Treatments on Snap Beans..273
Effect of Fallow Cultivation in Snap Beans (Regardless of Herbicides) - Live Oak 273
Effect of Fallow Herbicides on Snap Beans (Regardless of Tillage) - Live Oak..........273
Effect of Fallow Treatments on Weeds within Cabbage 274
Untreated Fallow Effect on Cabbage 274
Fallow Cultivation Effect on Cabbage 274
Fallow Herbicide Effect on Cabbage - Live Oak 275
Fallow Herbicide Treatment Effect on Weeds during Cabbage Crop - Citra 275
Fallow Treatment Effect on Cabbage Vigor and Yield - Citra 275
Effect of Pre-plant Herbicides on Cabbage 276

LIST OF REFERENCES...278

BIOGRAPHICAL SKETCH 283

LIST OF FIGURES

Figure page

1-1 Experimental design of Live Oak, FL experiment during the first year. 103

1-2 Purple nutsedge counts during the summer 2006 and 2007 fallow period in Live Oak, Fl 104

1-3 Effect of herbicides on purple nutsedge counts during the summer 2006 and 2007 fallow period in Live Oak, Fl...105

1-4 Effect of treatments on purple nutsedge counts during the summer 2007 fallow period in Live Oak, Fl. 106

1-5 Yellow nutsedge counts during the summer 2006 and 2007 fallow period in Live Oak, Fl...107

1-6 Effect of treatment by date interaction on yellow nutsedge counts during the summer 2006 and 2007 fallow period in Live Oak, Fl 108

1-7 Florida pusley counts during the summer 2006 and 2007 fallow period in Live Oak, Fl 109

1-8 Effect of herbicides on Florida pusley counts during the summer 2006 and 2007 fallow period 110

1-9 Effect of cultivation on Florida pusley counts during the summer 2006 and 2007 fallow period 111

1-10 Large crabgrass counts during the summer 2006 and 2007 fallow period in Live Oak, Fl 112

1-11 Interaction effect of treatment and date on large crabgrass counts during the summer 2006 and 2007 fallow period in Live Oak, Fl 113

1-12 Hairy Indigo counts during the summer 2006 and 2007 fallow period in Live Oak, Fl..114

1-13 Effect of herbicides on hairy indigo counts during the summer 2006 and 2007 fallow period 115

1-14 Browntop Millet counts during the summer 2006 and 2007 fallow period in Live Oak, Fl...116

1-15 Effect of treatment on browntop millet counts during the summer 2006 and 2007 fallow period in Live Oak, Fl...117

1-16 Effect of herbicides on browntop millet counts during the summer 2006 and 2007 fallow period 118

1-17 Carpetweed counts during the summer 2006 and 2007 fallow period in Live Oak, Fl ...119

1-18 Interaction effect of treatment and date on carpetweed counts during the summer 2006 and 2007 fallow period in Live Oak, Fl ...120

1-19 Purple nutsedge counts per 30 linear bed feet of row within a bell pepper crop during the spring of 2007 in Live Oak, Fl ...121

1-20 Effect of herbicides on purple nutsedge counts per 30 linear bed feet within a bell pepper crop during the spring of 2007 in Live Oak, Fl ...122

1-21 Effect of herbicides for Florida pusley counts located in the planting holes per 30 linear bed feet within a bell pepper crop during the spring of 2007 in Live Oak, Fl...123

1-22 Herbicide main effect for crabgrass counts per 30 LBF within the rows of a pepper crop during the spring of 2007 in Live Oak, Fl ...124

1-23 Cultivation main effect for crabgrass counts per 30 LBF within the rows of a pepper crop during the spring of 2007 in Live Oak, Fl ...125

1-24 Herbicide main effect for Florida pusley counts per m^2 located within the row middle of a pepper crop during the spring of 2007 in Live Oak, Fl ...126

1-25 Herbicide main effect for large crabgrass counts per m^2 located within the row middle of a bell pepper crop during the spring of 2007 in Live Oak, Fl ...127

1-26 Herbicide main effect for the average of six bell pepper heights in cm during the spring of 2007 in Live Oak, Fl...128

1-27 Herbicide main effect for the overall percentage of ground cover for all weed species combined in a snap bean crop during the spring of 2007 in Live Oak, Fl...129

1-28 Herbicide main effect for purple nutsedge counts per m^2 in the row of a snap bean crop during the spring of 2007 in Live Oak, Fl ...130

1-29 Herbicide main effect for Florida pusley counts per m^2 in the row of a snap bean crop during the spring of 2007 in Live Oak, Fl ...131

1-30 Herbicide main effect for large crabgrass counts per m^2 in the row of a snap bean crop during the spring of 2007 in Live Oak, Fl ...132

1-31 Cultivation main effect for large crabgrass counts per m^2 in the row of a snap bean crop during the spring of 2007 in Live Oak, Fl ...133

1-32 Purple nutsedge counts per 30 linear bed feet of row within a bell pepper crop during the fall of 2007 in Live Oak, Fl...134

1-33 Effect of herbicides on purple nutsedge counts per 30 linear bed feet within a bell pepper crop during the fall of 2007 in Live Oak, Fl ...135

1-34 Effect of fallow treatments on the control of purple nutsedge in the rows of a cabbage crop during the fall of 2007 in Live Oak, Fl 136

1-35 Pre plant herbicide main effect for the control of small flower morningglory in the rows of a cabbage crop during the fall of 2007 in Live Oak, Fl 137

1-36 Interaction effect of cultivation and pre plant herbicides on the control of Florida pusley in the rows of a cabbage crop during the fall of 2007 in Live Oak, Fl 138

1-37 Interaction effect of cultivation and pre plant herbicides on the control of large crabgrass in the rows of a cabbage crop during the fall of 2007 in Live Oak, Fl 139

1-38 Interaction effect of fallow herbicides and pre plant herbicides on the control of cutleaf evening primrose in the rows of a cabbage crop during the fall of 2007 in Live Oak, Fl 140

1-39 Main effect of pre plant herbicides on the control of large crabgrass in the rows of snap beans during the fall of 2007 in Live Oak, Fl....141

1-40 Main effect of pre plant herbicides on the control of cutleaf evening primrose in the rows of snap beans during the fall of 2007 in Live Oak, Fl....142

1-41 Main effect of pre plant herbicides on the control of smallflower morningglory in the rows of snap beans during the fall of 2007 in Live Oak, Fl....143

1-42 Main effect of fallow herbicides on the control of smallflower morningglory in the rows of snap beans during the fall of 2007 in Live Oak, Fl....144

1-43 Interaction effect of fallow herbicides and pre plant herbicides on the control of Florida pusley in the rows of snap beans during the fall of 2007 in Live Oak, Fl....145

1-44 Interaction effect of cultivation and pre plant herbicides on the control of Florida pusley in the rows of snap beans during the fall of 2007 in Live Oak, Fl 146

1-45 Main effect of fallow herbicides on the control of purple nutsedge in the rows of snap beans during the fall of 2007 in Live Oak, Fl....147

1-46 Main effect of pre plant herbicides on the number of cabbage per plot (15 LBF) during the winter of 2008 in Live Oak, Fl 148

1-47 Main effect of pre plant herbicides on the total cabbage weight during the winter of 2008 in Live Oak, Fl 149

1-48 Main effect of pre plant herbicides on the average cabbage weight during the winter of 2008 in Live Oak, Fl....150

2-1 Effect of different fallow treatments on the control of purple nutsedge during the first fallow season in Citra, Fl 199

2-2 Effect of different fallow treatments on the control of purple nutsedge during the first fallow season in Citra, Fl 200

2-3 Effect of different fallow treatments on the control of purple nutsedge during the second fallow season in Citra, Fl 201

2-4 Effect of different fallow treatments on the control of purple nutsedge during the second fallow season in Citra, Fl 202

2-5 Effect of different fallow treatments on the population density of purple nutsedge during the second fallow season in Citra, Fl....203

2-6 Effect of different fallow treatments on the population density of purple nutsedge during the second fallow season in Citra, Fl....204

2-7 Effect of different fallow treatments on the control of yellow nutsedge during the second fallow season in Citra, Fl 205

2-8 Effect of different fallow treatments on the control of yellow nutsedge during the second fallow season in Citra, Fl 206

2-9 Effect of different fallow treatments on the population density of yellow nutsedge during the second fallow season in Citra, Fl....207

2-10 Effect of different fallow treatments on the population density of yellow nutsedge during the second fallow season in Citra, Fl....208

2-11 Effect of different fallow treatments on the control of large crabgrass during the first fallow season in Citra, Fl 209

2-12 Effect of different fallow treatments on the control of large crabgrass during the second fallow season in Citra, Fl 210

2-13 Effect of different fallow treatments on the control of large crabgrass during the second fallow season in Citra, Fl 211

2-14 Effect of different fallow treatments on the population density of large crabgrass during the second fallow season in Citra, Fl....212

2-15 Effect of different fallow treatments on the population density of large crabgrass during the second fallow season in Citra, Fl....213

2-16 Effect of different fallow treatments on the control of goosegrass during the first fallow season in Citra, Fl 214

2-17 Effect of different fallow treatments on the control of goosegrass during the first fallow season in Citra, Fl 215

2-18 Effect of different fallow treatments on the control of goosegrass during the second fallow season in Citra, Fl 216

2-19 Effect of different fallow treatments on the population density of goosegrass during the second fallow season in Citra, Fl 217

2-20 Effect of different fallow treatments on the control of volunteer corn plants during the second fallow season in Citra, Fl 218

2-21 Effect of different fallow treatments on the control of volunteer corn plants during the second fallow season in Citra, Fl 219

2-22 Effect of different fallow treatments on the control of crowfootgrass plants during the second fallow season in Citra, Fl 220

2-23 Effect of different fallow treatments on the control of amaranth during the first fallow season in Citra, Fl 221

2-24 Effect of different fallow treatments on the control of amaranth during the first fallow season in Citra, Fl 222

2-25 Effect of different fallow treatments on the control of amaranth plants during the second fallow season in Citra, Fl 223

2-26 Effect of different fallow treatments on the control of amaranth plants during the second fallow season in Citra, Fl 224

2-27 Effect of different fallow treatments on the population density of amaranth during the second fallow season in Citra, Fl 225

2-28 Effect of different fallow treatments on the population density of amaranth during the second fallow season in Citra, Fl 226

2-29 Effect of different fallow treatments on the control of common purslane during the first fallow season in Citra, Fl....................227

2-30 Effect of different fallow treatments on the control of common purslane during the first fallow season in Citra, Fl....................228

2-31 Effect of different fallow treatments on the control of purslane plants during the second fallow season in Citra, Fl 229

2-32 Effect of different fallow treatments on the control of purslane plants during the second fallow season in Citra, Fl 230

2-33 Effect of different fallow treatments on the population density of purslane during the second fallow season in Citra, Fl 231

2-34 Effect of different fallow treatments on the population density of purslane during the second fallow season in Citra, Fl 232

2-35 Effect of different fallow treatments on the control of Florida pusley during the first fallow season in Citra, Fl 233

2-36 Effect of different fallow treatments on the control of Florida pusley plants during the second fallow season in Citra, Fl 234

2-37 Effect of different fallow treatments on the control of Florida pusley plants during the second fallow season in Citra, Fl 235

2-38 Effect of different fallow treatments on the population density of Florida pusley during the second fallow season in Citra, Fl...236

2-39 Effect of different fallow treatments on the control of cutleaf evening primrose during the first fallow season in Citra, Fl 237

2-40 Effect of different fallow treatments on the control of cutleaf ground cherry plants during the second fallow season in Citra, Fl...238

2-41 Effect of different fallow treatments on the control of cutleaf ground cherry plants during the second fallow season in Citra, Fl...239

2-42 Effect of different fallow treatments on the population density of cutleaf ground cherry during the second fallow season in Citra, Fl..240

2-43 Effect of different fallow treatments on the population density of cutleaf ground cherry during the second fallow season in Citra, Fl..241

2-44 Effect of different fallow treatments on the control of carpetweed plants during the second fallow season in Citra, Fl 242

2-45 Effect of different fallow treatments on the control of carpetweed plants during the second fallow season in Citra, Fl 243

2-46 Effect of different fallow treatments on the population density of carpetweed during the second fallow season in Citra, Fl 244

2-47 Effect of different fallow treatments on the population density of carpetweed during the second fallow season in Citra, Fl 245

2-48 Effect of different fallow treatments on the control of redweed plants during the second fallow season in Citra, Fl 246

2-49 Effect of different fallow treatments on the control of purple nutsedge plants during the second crop season (cabbage) in Citra, Fl..247

2-50 Effect of different pre-plant herbicide treatments on the control of purple nutsedge plants during the second crop season in Citra, Fl 248

2-51 Effect of different fallow treatments on the control of yellow nutsedge plants during the second crop season in Citra, Fl 249

2-52 Effect of different fallow treatments on the control of crabgrass plants during the second crop season in Citra, Fl 250

2-53 Effect of different pre-plant herbicide treatments on the control of crabgrass plants during the second crop season in Citra, Fl....251

2-54 Effect of different pre-plant herbicide treatments on the control of cutleaf evening primrose plants during the second crop season in Citra, Fl 252

2-55 Effect of different fallow treatments on the control of purslane plants during the second crop season in Citra, Fl 253

2-56 Effect of different pre-plant herbicide treatments on the control of purslane plants during the second crop season in Citra, Fl.....254

2-57 Effect of different fallow treatments on the population density of purple nutsedge plants during the second crop season in Citra, Fl 255

2-58 Effect of different pre-plant herbicide treatments on the population density of yellow nutsedge plants during the second crop season in Citra, Fl 256

2-59 Effect of different pre-plant herbicide treatments on the population density of large crabgrass plants during the second crop season in Citra, Fl 257

2-60 Effect of different fallow treatments on cabbage vigor during the second crop season in Citra, Fl 258

2-61 Effect of different fallow treatments on cabbage stand establishment during the second crop season in Citra, Fl 259

2-62 Effect of different fallow treatments on total cabbage weight per plot (15 LBF of row) during the second crop season in Citra, Fl 260

2-63 Effect of different fallow treatments on average cabbage weight during the second crop season in Citra, Fl 261

2-64 Effect of different pre-plant herbicide treatments on total cabbage weight per plot (15 LBF of row) during the second crop season in Citra, Fl....262

2-65 Effect of different pre-plant herbicide treatments on average cabbage weight per plot (15 LBF of row) during the second crop season in Citra, Fl 263

2-66 Effect of different summer fallow treatments on the long term control of purple nutsedge after the harvest of the second crop in Citra, Fl..264

2-67 Effect of different summer fallow treatments on the long term control of large crabgrass after the harvest of the second crop in Citra, Fl...265

2-68 Effect of different summer fallow treatments on the long term control of Florida pusley after the harvest of the second crop in Citra, Fl 266

2-69 Effect of different summer fallow treatments on the long term control of common purslane after the harvest of the second crop in Citra, Fl 267

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CHEMICAL AND MECHANICAL FALLOW WEED CONTROL METHODS IN FLORIDA VEGETABLE CROPS

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Field experiments were conducted in Live Oak and Citra, Florida during the summers of 2006 and 2007 to determine the efficacy of fallow weed control methods on controlling weeds during the fallow season, controlling weeds during the growing season, and their influence on crop yields. Furthermore, several pre-plant herbicides were used to determine weed control efficacy for certain weeds and their effect on crop yield, when used in conjunction with fallow weed control methods. Fallow weed control treatments included an untreated check, a cultivated check, post-emergent herbicides, pre-emergent herbicides, systemic herbicides, contact herbicides, combinations of herbicides with cultivation and combinations of herbicides with each other. The broad spectrum herbicides used for fallow weed control were glyphosate, paraquat, glyphosate tank-mixed with halosulfuron, glyphosate mixed with trifloxysulfuron, glyphosate tank-mixed with s-metolachlor, paraquat tank-mixed with trifloxysulfuron and paraquat tank-mixed with s-metolachlor. The pre-plant herbicides used were oxyfluorfen and s-metolachlor for cabbage. EPTC, s-metolachlor, and pendimethalin were used for snap beans. In peppers, EPTC, s-metolachlor, and clomazone were applied under the plastic.

Leaving the field idle during the fallow period provided unacceptable weed control during the fallow and crop. In addition, the untreated check resulted in the lowest cabbage yields.

Cultivation controlled emerged broadleaf and grassy weeds during the fallow period, but did not provide pre-emergent or substantial long term weed control during the crop. Cultivation increased purple nutsedge compared to the untreated control in Live Oak. In Citra, cultivation decreased nutsedge significantly compared to the untreated control. However, cultivation did not reduce purple nutsedge to an acceptable level for crop production. Glyphosate and paraquat both provided post-emergent control of all weeds present; however, no pre-emergent activity was provided. S-metolachlor provided pre-emergent activity, increased total control of yellow nutsedge, crabgrass, and various broadleaf weeds during the fallow period. Halosulfuron did not improve weed control or yields beyond that provided by glyphosate alone. Trifloxysulfuron increased purple and yellow nutsedge control when added to glyphosate or paraquat. In addition, trifloxysulfuron provided excellent pre-emergent and long term broadleaf weed control. However, trifloxysulfuron negatively impacted cabbage vigor, and yield.

CHAPTER 1
LITERATURE REVIEW

Introduction

Fallowing and Fallow Weed Control

Fallow Land is defined as:“Cropland that is not seeded for a season; it may or may not be plowed. The land may be cultivated or chemically treated for control of weeds and other pests or may be left unaltered. Allowing land to lie fallow serves to accumulate moisture in dry regions or to check weeds and plant diseases. As a method of restoring productivity, rotation of crops is now preferred to fallowing, which is considered wasteful of humus and nitrogen” (The Columbia Encyclopedia).

Reasons for Fallowing

There are several reasons why fallow weed control is important in Florida vegetable crops including; 1) the loss of methyl bromide, and 2) the lack of weed control options during the cropping season

Methyl-bromide is a soil fumigant used in many vegetable crops that provides total weed control; however it has been banned under the Montreal Protocol and is being phased out (VanSickle et al., 2000, Schneider et al., 2003, Deepak et al., 1996).

Registered pre-plant herbicides labeled for weed control in Florida vegetable crops are selective and do not provide adequate control of many common weeds (Stall and Gilreath, 2005). Johnson and Mullinix (1998) reported that acceptable weed management in cucumbers is difficult because registered herbicides are generally not effective in controlling large-seeded dicot weeds or perennial sedges. Fewer herbicides are registered for vegetable crops due to lower acreage and fewer herbicide sales. In addition, liability for herbicide manufactures is higher due to higher crop value per unit area in vegetable crops.

Post-applied herbicides in vegetables often lack selectivity and generally can only be used to control weeds in row middles during the cropping season. There are few labeled post emergent herbicides that can be applied over the top of the crop without either injuring the crop or provide adequate control of multiple weed species. All these reasons support fallow weed control,where there are fewer drawbacks associated with weed control than during the cropping season. Tillage, broad spectrum herbicides, including those that translocate within the plant and posssesing residual control may be implemented during the fallow season. Weeds present during planting and early crop development have the most negative impact on crop yields (Knezevic et al., 1997). According to Stall (1999), fallow weed control can also be used to reduce the seed rain of sexually propagated weeds. In addition, fallow treatments can be used to reduce asexually propagated weeds. Lastly, weed control during the fallow period can play an important role in reducing diseases and insects that are harbored between crops in susceptible alternate weed host species.

Weeds: Explanations and Problems

A simple definition of a weed is any plant growing where it is not wanted (Anderson, 1996; Radosovich et al., 1997). Weeds negatively impact crops by increasing the time and costs of production. They also interfere with mechanical and hand harvesting, and reduce crop yields and produce quality. Even volunteer crop plants from a previous season can act as a weed during the following crop. In cropping systems weeds are the first plant species to colonize disturbed areas. Therefore, weeds are those plants which are best able to adapt to the constant changes involved in crop production such as land preparation, tillage, cultivation, and herbicide use (Anderson, 1996).

Sexual and Asexual Reproduction

Weeds that reproduce by seeds are sexually propagated. In asexual propagation the vegetative parts such as bulblets, bulbs, corms, roots, rhizomes, stolons and tubers are the reproductive organs. Many plants can propagate by both sexual and asexual means (Booth et al., 2003). Annual weeds are spread near and far by their seeds. Locally perennial plants are distributed by both sexual and asexual reproduction. Perennial plants are spread far by the dissemination of their seeds. Weed propagules are naturally disseminated by wind, flowing water, and animals. The distribution of seeds and vegetative propagules may be aided by farm and transportation equipment. Seeds are spread easily by harvesting equipment that travels from one field to another. Seeds can also be spread in contaminated crop seeds. Weeds that reproduce asexually are spread by tillage which cuts and distributes the vegetative parts throughout the field and into other fields that the machinery is used in. Both sexual and asexual reproductive organs can be transported long distances on transportation equipment such as trucks, trains, boats, and airplanes (Anderson 1996).

Characteristics of Weeds

There are common characteristics that weeds tend to posses, therefore plants that do not posses these characteristics are unlikely to be classified as weedy. These characteristics have allowed weeds to become tolerant to abiotic environmental variations within the species. The ideal weed characteristics include plants that: 1) have seeds that can germinate in many environmental conditions, 2) have seeds that posses discontinuous germination and longevity, 3) grow rapidly through the vegetative phase to flowering, 4) produce seeds continuously throughout the growing season, 5) are self compatible by not necessarily autogamous or apomictic, 6) don’t require specialized pollinators or can pollinate by wind, 7) produce prolific amounts of seeds in favorable growing conditions, 8) are able to produce seeds under a wide range of conditions (tolerant and plastic, 9) are adapted for short and long distance dispersal 10) have vigorous vegetative reproduction or can grow from plant fragments for perennials, 11) are brittle and cannot be pulled from the ground type perennials, 12) are able to compete interspecifically by special modes such as rosettes, choking growth and allelopathy (Baker, 1974).

Basically, weeds have different strategies for survival to stressful conditions and poses competitive advantages compared to other plants. As discussed earlier many annual weeds produce a large number of seeds to ensure future generations. For example, crabgrass can produce between 909 and 3,160 seeds/plant depending on density (Aguyoh and Masiunas 2003a).

Stevens (1932) investigated the number of seeds produced by certain weeds. He found that the plant families which produced the most abundant amount of seeds averaged across species are Poaceae (annuals- 17,891 seeds/plant , perennials- 11,640 seeds/plant), Polygonaceae (annuals-17,945 seeds/plant, perennials- 21,883 seeds/plant), Chenopodiaceae (annuals- 27,000 seeds/plant), Brassicaceae (annuals- 15,717 seeds/plant), and Asteraceae (annuals- 3,816 seeds/plant, perennials- 10,833 seeds/plant). Coincidently many plants in these families are weeds precisely because they produce prolific numbers of offspring. In addition, individual weed species that produce many seeds are: *Cyperus esculentus* L. (2,420 seeds/plant), *Digitaria sanguinalis* (27,100 seeds/plant), *Amaranthus retroflexus* L (117,400 seeds/plant), *Portulaca oleracea* L. (52,300 seeds/plant) and *Rudbeckia hirta* L. (1,615 seeds/plant).

In regards to seed longevity, dormancy and germination, Masin et al. (2006) found that crabgrass seed viability was reduced 5-10% during the first 3 months. In addition, crabgrass seed viability declined to 50% after 448-492 days. Crabgrass seed viability was less than <1%

after 1200 days. However, goosegrass seed viability remained high after 3 years and values decreased to less than 80% after 1158 days. They found that crabgrass germination was higher in late spring and early summer and lower in late autumn and winter. However, goosegrass seed did not exhibit dormancy. Germination was nearly 100% in the spring and autumn and about 85% in summer and winter for goosegrass.

Crop-Weed Competition

Competition between two plants occurs when the supply of light, water, nutrients, physical space, temperature and other factors essential to growth or development are not provided optimally for the demands of both plants (Anderson, 1996). Therefore, competition is detrimental to the growth and development of one or all of the plants competing for resources. Competition between plants can be enhanced by allelopathy, which is when the growth of one plant is biochemically inhibited by the production of phytotoxic compounds of another plant. Interference refers to all the direct and indirect effects one plant has on another. Characteristics of weeds that successfully compete with crops are; plants that have an aggressive growth habit, more efficiently utilize resource that are needed by the crop and/or produce allelopathic substances. Crop-weed competition for resources can drastically reduce crop yields and possibly crop quality. The amount of reduction in crop yields by weed competition depends on the weed species, the timing of crop-weed emergence, duration of competition, density of weeds, crop spacing, proximity of weeds to crop, crop planting date (season), climatic and environmental conditions. Generally, broadleaves are more competitive than grasses. However, competitiveness among grass and broadleaf species vary.   Intuitively, as weed densities increase crop yields decrease regardless of the competitive ability of a single plant.

Critical Weed-Free Period

The critical weed free period is the time during crop production that the presence of weeds has the greatest impact on reducing crop growth and yields. During this critical time period weed-control must be implemented to prevent unwanted crop yield losses. The crop should be kept weed free during this critical period of development. However, once the crop is established and able to gain a size advantage during this critical period of time it can successfully outcompete later emerging weeds, mainly by shading. In general, annual crop yields are most adversely affected by weed competition during the first 4-6 weeks after crop planting. Therefore, weed emergence relative to crop emergence is important in crop-weed competition. In general, weeds that emerge before or with the crop plant compete with the crop and reduce by growth and yields. For example, early emerging crabgrass decreased yield in snap beans more than late emerging crabgrass. Densities as low as 1 crabgrass plant/m row can reduce snap bean yields when they emerge early in the season (Aguyoh and Masiunas 2003a). The duration of crop-weed competition is very important as well. Sometimes the growth of the plant is not hindered by a certain period of competition but later yields are compromised by extended periods of competition. Weed competition can cause delayed ripening and harvests, even if total yields are not compromised. Harvesting delays can be detrimental to farmers that are competing with each other for early season market opportunities when crop prices are highest.

Monks and Schultheis (1998) conducted a critical weed-free period study for large crabgrass (*Digitaria sanguinalis*) in transplanted watermelon (*Citrullus lanatus*). Their results indicated that triploid watermelon marketable weight and fruit number per hectare declined linearly the longer crabgrass competition occurred. In addition, high densities of large crabgrass (250 to 300 plants/m2) caused a marketable yield decrease of roughly 5,582 kg and a loss of approximately 911 fruit for every week of competition. Marketable fruit yield and fruit number increased in a quadratic fashion in response to delaying the emergence of crabgrass for up to 6 weeks. Yield was increased by 880 kg and 151 fruit per hectare for every week crabgrass emergence was delayed. Large crabgrass emerging after 6 weeks did not affect watermelon yield. Therefore, the critical weed-free period for large crabgrass in transplanted triploid watermelon is between 0 and 6 weeks.

Host plants for pests

Weeds may act as an alternate host for insects and diseases to overwinter and re-infest crops (Anderson, 1996). Many insects and diseases use weed species related to the crop as an alternate host, this is true for tomatoes and solanaceous weeds. Mossler et. al, (2006) described nightshade and dodder as common weeds in pepper that facilitate diseases American black nightshade (*Solanum americanum*) is a broadleaf weed that serves as an alternative host for nematodes, diseases, and virus-vectoring insects. Another weed that is problematic in peppers is dodder. Dodder is a parasitic plant that infects crops or weeds. If dodder is growing on an infected pepper plant, it is capable of bridging the disease to another healthy pepper plant within the row (Mossler et al., 2006).

Weed species in the solanum family include nightshade species, buffalo bur, and horsenettle. These plants are suitable hosts for pests that attack solanaceous crops such as tomato, pepper, and potato. Pests of solanaceous crops include whiteflies, various viruses, Colorado potato beetle, and cabbage looper. Morningglories can serve as a host to pests that attack sweet potatoes such as the sweet potato weevil. Beet western yellows virus can be found in pigweeds. Purple nutsedge and goosegrass can become infected by barley yellow dwarf virus. In addition, many weeds can serve as host plant for insects that are widespread and not host specific.

Common and Troublesome Weeds in Vegetable Crops

The Southern Weed Science Society Proceedings (1999) indicate that the ten most common weeds in Florida vegetable crops are pigweed spp., yellow nutsedge, common lambsquarter, goosegrass, panicum, nightshade, common ragweed, common purslane, crabgrass, and Florida pusley. The ten most troublesome weeds in Florida vegetable crops are yellow nutsedge, purple nutsedge, parthenium, nightshade, morningglory, eclipta, common ragweed, common bermudagrass, Brazilian pusley, and sicklepod.

Webster and MacDonald (2001) performed a farmer survey in Georgia of different crops and compiled a list of the most troublesome weeds. In Georgia vegetable crops nutsedge species (purple and yellow) were listed as the most troublesome weeds, followed by pigweed species, sicklepod, swinecress, cutleaf eveningprimrose, wild radish, bristly starbur, Texas panicum, Florida beggarweed, and tropic croton.

Holm et al. (1977) wrote a book on the world's worst weeds. Many of the problematic weeds throughout the world are found in Florida vegetable crops. Some of these weeds include: *Cyperus rotundus L.*, *Eleusine indica* (L.) Gaertn., *Portulaca oleracea* L., *Digitaria sanquinalis* (L.) Scop., *Amaranthus hybridus*, and *Cyperus esculentus* L. Listed below are descriptions of these weeds.

Cyperus rotundus L.

Cyperus rotundus L. is a member of the Cyperaceae (sedge family) and is commonly known as nutgrass, nutsedge or purple nutsedge. Purple nutsedge is the world's worst weed. (Holm et al., 1977). This sedge is native to India. The leaves are very dark green, the stem is three-sided, the plant grows up to 100 cm tall on moist fertile soils and it has an intricate underground system of rhizomes and tubers. In fact, the rhizomes are known to penetrate and gouge through root crops. Purple nutsedge produces prolific subterranean tubers that can withstand harsh weather conditions such as heat, drought and flooding through dormancy mechanisms. The inflorescence is reddish to purplish brown, this is the premise for its common name of purple nutsedge. Purple nutsedge is a weed that infests 52 crops in 92 countries (Holm et al., 1977). Neeser et al (1997) conducted a study on the survival and dormancy of purple nutsedge and found that purple nutsedge has the ability to reenter dormancy after already sprouting. Therefore nutsedge has primary and secondary dormancy.

Siriwardana and Nishimoto (1987) investigated the distribution of propagules within the soil profile. They reported that the number of purple nutsedge tubers decreased with soil depth. The vast majority of nutsedge tubers are present in the top 15 cm to soil. Six weeks after rototilling and irrigating the soil the distribution of purple nutsedge at various depths are as follows: 45% of tubers are located in the top 4cm of the soil profile, 34% of tubers are between 4 to 8 cm soil depth, 16% of tubers are between 8 to 12 cm soil depth, 4% of tubers are located between 12 to 16 cm soil depth and only 1 % of tubers are located between 16 and 30 cm of soil depth. The fresh weight, dry weight, and percentage of dry matter per tuber increased with soil depth. They explained that purple nutsedge may store more carbohydrate reserves deeper in the soil as a survival mechanism during environmental stress conditions which tend to fluctuate more dramatically near the soil surface. Six weeks after field preparation and irrigation, 51% of the nutsedge tubers were from the parent population (70% were connected to aerial parts and 30% did not sprout), 16 % were from new tubers and 33% were new corms. Six weeks after tillage the relationship between the number of total tubers and the tuber number in a chain decreased exponentially. In other words, most of the tubers were not attached to other tubers and the number of tubers that were contained in large chains were very small.

***Eleusine indica* (L.) Gaertn.**

The common name for *Eleusine indica* is goosegrass and it belongs to the Poaceace (grass) family. It is a densely clumping annual grass and is one of the most serious weedy grasses of the world. The origin of goosegrass is disputed, however it is thought to have come from China, India, Japan, Malaysia, and Tahiti. The distribution of this weed ranges for Natal in South Africa to Japan and the northern border of the United States. It is a weed problem in 46 crops in 60 countries. Beneficial uses of goosegrass include its use as a hay and silage in some regions of the world and that it is grown for seeds in Africa and Asia (Holm et al., 1977).

***Portulaca oleracea* L.**

Portulaca oleracea is a member of the Portulacaceae (purslane) family and is know as common purslane. It is an annual herb that has succulent, fleshy stems that can grow either upright or prostrate depending on the light conditions. It is thought to originate from Europe, however its succulent nature suggest that it is a desert plant or a desert border plant and therefore it may be native to North Africa. It is a weed in 45 crops of 81 countries. Since it was one of the early vegetables it was distributed by man from place to place. It has been widely used as pig food (Holm et al., 1977).

***Digitaria sanguinalis* (L.) Scop.**

Digitaria sanguinalis, commonly known as large crabgrass is a member of the Poaceae (grass) family. It is an annual grass that is a problematic weed worldwide that thrives in both temperate and tropical climates. It is native to Europe and has a wide distribution extending from latitude 50º N to 40º S. Crabgrass is a weed in 56 countries and is found in 33 crops. Sometimes this grass is used for grazing and for hay (Holm et al., 1977).

Amaranthus hybridus

Amaranthus hybridus commonly known as pigweed and smooth amaranth belongs to the Amaranthaceae (amaranth) family. The annual herb has an erect growth habit and is native to North America. It is found throughout the Americas and has spread to Africa and south-central Asia. It is reported to be a weed in 27 crops in 27 countries. It is often consumed as a green vegetable in southern Africa and India (Holm et al., 1977).

Cyperus esculentus L.

Cyperus esculentus, also known as yellow nutsedge is in the Cyperaceae (sedge) family. It is a light green perennial sedge with three-sided stems and it can grow up to 1 meter tall. Basal bulbs are formed by the swelling of the stem underneath the ground and rhizomes grow from this bulb to a single terminal underground tuber. Distinguishing characteristics between yellow and purple nutsedge is that yellow nutsedge has a yellow inflorescence and produces a single tuber per rhizome, contrasted with purple nutsedge that has a purplish inflorescence and produces rhizomes with multiple darker colored tubers in a chain. The rate of propagation is very fast for yellow nutsedge. One tuber can produce 1,900 plants, almost 7,000 tubers, and cover an area of approximately 2 meters in diameter within a single year. The sweet, oily, fleshy tubers can be used for human consumption. The weed has been cultivated to produce tubers for pig feed. Yellow nutsedge is a weed in 21 crops in more than 30 countries around the world (Holm et al., 1977).

Negative Impact of Weeds in Various Crops

Weeds have different growth habits, morphological structures, and survival techniques which cause them to compete differently with between crops. Season long competition of 8 crabgrass/m row reduced snap bean yields from 46 to 50% (Aguyoh and Masiunas 2003a). Aguyoh and Masiunas (2003b) also found that 8 redroot pigweed plants/m row reduced snap bean yield 39 – 42 % for early emerging weeds (weeds seeded with the crop). Late emerging redroot pigweed (seeded at the first trifoliate leaf stage) reduced snap bean yields between 48 – 58 % at the same density. Santos et al. (1997) found that season long interference of smooth pigweed and common purslane caused a reduction of field grown lettuce yields of 24 and 48% respectively. These yield reductions occurred when pigweed density was between 8 and 16 plants per 6 m of row and purslane density was 16 plants per 6 m of row. Santos et al (2004) described the mechanisms of smooth pigweed and common purslane interference with lettuce as influenced by phosphorous.

They concluded that smooth pigweed interfered with lettuce primarily due to light interception from its taller canopy. Luxury P absorption by pigweed was a secondary interference mechanism with lettuce. In contrast, common purslane primarily competed for P, and due to the increased canopy height, light interception became a secondary interference factor. Thus banding P instead of broadcasting may reduce the lettuce yield losses from competition by smooth pigweed, and common purslane.

Kadir et al (1999) concluded that 7.4 purple nutsedge/ft^2 reduced tomato yields 14% when competing for the entire growing season. Morales-Payan et al. (1997a) found that 18.6 purple nutsedge/ft^2 reduced bell pepper yields by 32% when allowed to compete season long.

Johnson and Mullinix (1999) found that 1.4 yellow nutsedge/ft^2 allowed to compete all growing season decreased cucumber yields by 5%.

William and Warren (1975) found that season long competition of purple nutsedge at high densities reduced yields of garlic by 89%, okra by 62%, green bean by 41%, cucumber by 43% and cabbage by 35% in experiments conducted in Brazil. In 1997, Morales-Payan and Stall demonstrated that full season competition with purple nutsedge decreased eggplant yields by

22%. Morales-Payan et al. (1997b) found that purple nutsedge caused up to 40% yield loss in tomato in experiments conducted in the Dominican Republic.

Buker et al. showed that full season yellow nutsedge competition reduced watermelon yield by 98%. According to Dusky et al. (1997) rice yields were reduced by 23% due to season long competition with yellow nutsedge. Keeley and Thullen (1975) reported that yellow nutsedge allowed to compete for the entire growing season reduced the yield of cotton by 34%.

Morales-Payan et al. (2003) conducted a study to determine the above and below ground interference of purple and yellow nutsedge with tomato. They found that dry tomato shoot weights decreased with full (both above and below ground competition), aboveground, and belowground interference with purple nutsedge. Full competition decreased tomato shoot dry weight by 28 % compared to tomato plants grown without purple nutsedge competition.   Below ground competition with purple nutsedge decreased tomato dry shoot weights by 15%.

Morales-Payan et al. (2003) tomato plants in full or above ground competition with yellow nutsedge were 20% taller than tomatoes grown without yellow nutsedge competition and tomatoes competing underground with yellow nutsedge. This effect was attributed to tomato elongation to outcompete yellow nutsedge for sunlight. Full yellow nutsedge interference decreased tomato shoot dry weight by 34%. Above or belowground competition with yellow nutsedge decreased tomato dry shoot weights by 19% compared to the weed free tomato check. The authors concluded that purple nutsedge primarily competed with tomato by underground interference. However, in yellow nutsedge both above ground and belowground interference with tomato were important.

Methyl Bromide Alternatives

Methyl bromide is a broad spectrum fumigant that has been identified as essential for the production and marketing of many fruit and vegetable crops, it is used for the control of a variety of soil-borne pests and pathogens (VanSickle, 2000, Deepak et al., 1996). This chemical is used as a pre-plant material and is usually combined with chloropicrin to manage several soil-borne pests and pathogens that include nematodes, fungus, insects, weed seeds, and weed vegetative propagules (specifically nutsedge) in high value fruits, nuts, vegetables, nursery and ornamental crops (Deepak et al., 1996; Schneider et al., 2003). In addition it is used for the post-harvest control of pests and pathogens on fresh produce and durable commodities (Schneider et al., 2003). It can also be used to control termites, cock roaches, and rodents in buildings.

Methyl bromide is injected into the soil during soil preparation. It is then covered by polyethylene film that prevents the escape of this volatile gas. The polyethylene mulch will then serve as a barrier to prevent weed growth and moisture loss from the soil. In this plasticulture system, the fumigated area is left for two weeks (10-14 days), before holes are punched into the mulch and transplants are planted. A second crop may be planted into the same plastic mulch depending on the condition of the mulch and the market conditions (Deepak et al., 1996). The reason the use of methyl bromide was so prevalent is because of its effectiveness and economic feasibility to control many pests with only one application prior to planting the crop.

Unfortunately, methyl bromide has been designated as a Class I ozone depleter (Deepak et al., 1996; VanSickle, 2000, Deepak et al., 1996). Therefore, methyl bromide has been banned under the Montreal Protocol (an international treaty) and the US Clean Air Act, and is gradually being phased out. Originally the U.S. Clean Air Act of 1992 required that Class I ozone depleting chemicals be banned within seven years of their classification, thus U.S. regulators issued a complete ban on methyl bromide by January 1, 2001. Since January 2001, methyl bromide use was restricted to 50% of the amount used in 1991. In 2003, the available amount of methyl bromide was restricted to 30% of the 1991 levels and a complete ban was imposed in

2005, excluding quarantine uses. (Schneider et al., 2003; VanSickle, 2000; Deepak et al., 1996). This leaves Florida vegetable growers in a serious dilemma, since pre-plant soil fumigation is a standard procedure in high value vegetable crops such as strawberries, tomatoes, peppers, eggplant, cucumbers, squash, and watermelons. These include crops that are used in a double cropping system in Florida, meaning a primary crop (tomatoes, peppers, eggplant) is produced and the inputs from the primary crop are utilized to produce a second crop of shorter maturity (cucumbers, squash, watermelon) on the same area of land. Naturally a ban on methyl bromide may affect the production of these crops (VanSickle et al., 2000, Deepak et al., 1996). A methyl bromide ban will be even more detrimental to Florida production for winter crops, since Florida is the state that supplies the majority of vegetables to the U.S. market during November through May. Critical use exceptions have been issued for certain crops. However, the critical use exemptions have to be reinstated and will eventually expire and alternatives to methyl bromide need to be developed.

Unless there is a 'silver bullet' broad spectrum cure all that can replace the role methyl bromide has served in the past, it seems a 'silver buck shot' integrated approach is needed to control specific pests. To control a specific pest, a management strategy must 1) effectively control the pest, 2) prove effective under local soil conditions, 3) be economically feasible and 4) be environmentally friendly. Possible solutions that meet this criteria to control specific pests include plant growth promoting rhizobacteria, suppressive soils, soil amendments, mulches, crop rotation, host resistance, new chemicals, and new application techniques for chemical alternatives, biological control, and fallow (Schneider et al. 2003). Scientists at USDA sponsored meetings identified methyl bromide alternatives that growers will most likely adopt and the expected impacts these alternatives will have on costs and yields of several crops. In general, Florida growers were predicted to switch to a fumigant and herbicide combination (1,3-dichloropropene/chloropicrin/herbicide) as a replacement to methyl bromide (VanSickle et al., 2000). This speculation is confirmed by Deepak (1996), who suggests that a fumigant such as Telone© or Vapam© would be used to control nematodes and diseases and a herbicide would be used for weed control. He found that the pre harvest production costs per acre differ slightly between methyl bromide and no methyl bromide systems.

However, the main impact of the methyl bromide loss would be on the reduction of yields per acre. Telone© or Vapam© coupled with a herbicide will provide an inferior control of weeds compared to methyl bromide, especially nutsedge. The loss of methyl bromide would also make vegetables more susceptible to soil-borne pests. In double cropping systems the first crop yield reductions range from 15-40% and the second crop yield losses would be higher ranging from a 20 to 50% reduction. The larger yield losses are attributed to the projected degradation of the plastic mulch in the second crop due to reduced weed control.

In Palm Beach and Dade counties the projected yield losses from a methyl bromide ban are greater because of less land available for production. Areas in southwest and west central Florida would be able to move production and escape the "old land disease" (Deepak et al., 1996). Production would cease in Palm Beach county for tomatoes, peppers, eggplants, and cucumbers. In addition, the production areas in the southwest and west central areas of Florida would be adversely affected, however west central Florida would remains substantial producer of tomatoes and peppers. Much of the production loss in Florida would be gained by the Mexican fresh vegetable industry. Florida is expected to retain a majority of the green pepper market in April and May. Both Texas and Mexico are expected to gain market share, since neither region is affected by the ban on methyl bromide. Florida FOB (Freight On Board) revenues from the six major crops (tomato, pepper, eggplant, cucumber, squash, watermelon) are projected to decrease by 53% and Mexican FOB revenues for these crops are projected to increase by 65%. FOB revenue from bell pepper will more than double in Texas. On average the whole sale price of peppers is expected to increase by 4 % across the U.S. due to a ban on methyl bromide. The southeast and northeast markets are expected to see the greatest price increase due to the methyl bromide ban and the decreased Florida production of fresh winter vegetable crops (Deepak et al., 1996). As a logistical problem, it should be noted that Telone requires additional personal protective equipment by applicators and field workers.

Pepper growers in Florida are assumed to switch to a Telone C17/Devrinol combination. Predicted pre harvest costs of this alternative range from a decline of $41 per acre in West Central Florida to an increase of $397 per acre in Palm Beach County. Furthermore, pepper yields are expected to decline 25% in Dade County, because of the restrictions on Telone use in that area, but the yield is predicted to decline 15% in all other areas of Florida. Due to the ban on methyl bromide the acreage of bell peppers in Florida is expected to experience a 65% decline. This will lead to increased pepper production in Texas and Mexico, since neither of these areas use methyl bromide as a predominant production practice. Even with the increased acreage in Mexico and Texas, total pepper production is expected to decline by 12.3% and wholesale bell pepper prices are predicted to increase by 4.5%. Lastly, a decrease of $37.8 million is expected for the loss of total shipping point revenues for peppers, with Florida suffering a $134.8 million loss in shipping point revenues. Florida shippers may lose $218.4 million in shipping point revenues across all crops, if better alternatives to methyl bromide are not found. Due to the decline in produce quantity and an increase in the price paid for those products, the consumer surplus is expected to decline by $111.7 million dollars due to the ban of methyl bromide (VanSickle et al., 2000). Deepak et al. (1996) also suggest that a ban on methyl bromide would not only hurt producers but consumers as well. In addition, he suggests that Mexico will provide the bulk of the U.S. winter vegetable market in the void that a ban on methyl bromide would create. Since the resulting economic impact from the loss of methyl bromide will be severe, we need to explore new alternatives to maintain our vegetable production in Florida. In summary, the availability of methyl bromide has drastically decreased, its cost has dramatically increased, and it will be gone someday. In order to control the pests and diseases that methyl bromide successfully hindered, an integrated approach has to be taken. Individual methods may have to be implemented to control each individual pest separately. One feasible option to lower the weed pressure prior to planting (and thus increase crop yields) is to implement fallow weed control methods that utilize herbicides and/or tillage. Fallowing can also be used to decrease disease pressures in cropping systems.

Tillage

Soil disturbance is the simplest and oldest method of weed control. Many countries today still rely largely on mechanical tillage, hand hoeing, and pulling weeds as the primary method of controlling weeds. Tillage disturbs the roots and hinders the plants of the ability to uptake water and nutrients necessary for growth. However, tillage can cause a shift in the weed spectrum to favor rudimentary species that are adapted to constant disturbances. Tillage can be used successfully alone to control certain weeds, but other weeds can thrive under these conditions when competition is removed. Seeds within the soil can be either buried by tillage or can be brought to the surface. Buried seeds will remain dormant, not germinate, and eventually die. Seeds that are brought to the surface will have the opportunity to germinate and this is the reason tillage causes a flush of weeds when implemented. Creating a situation where a flush of weeds is induced is a helpful management tool to kill emerging weeds all at once.

However, tillage can have negative impacts on weed control efforts. Cultivation can propagate vegetative materials by cutting them into pieces and depositing them into the soil. Mechanical tillage is easily implemented on fallow land. However, in a crop, tillage can only be performed in row middles and will not remove weeds within the row. Supplemental hand weeding, hand hoeing, or selective herbicides are needed to control weeds near the crop plants. In summary, tillage is a good tool to control certain weeds under certain situations but additional tools are need to effectively manage weed pressure in vegetable crops.

Seed Bank (Survival and Dormancy)

The soil seed bank represents the seeds that are in the soil profile. Understanding and managing the soil seed bank is a necessity to weed control. Some seeds have mechanisms which allow them to remain viable in the soil for a long period of time, whereas some seeds are short lived in the soil. Dormancy mechanisms allow seeds to remain in the soil without emerging until environmental conditions are favorable. Seeds and vegetative reproductive parts have different survival and dormancy mechanisms. In general, seeds can survive longer than vegetative structures. In order to effectively manage the seed bank, seed rain, seed dormancy, and seed survival must be taken into account for each species. If the weeds are killed before matutation and seed production then less offspring will be deposited into the soil. Therefore it is important to control weeds before seed set and/or spread through vegetative propagation. Understanding dormancy is critical to weed control because different environmental cues are needed to break dormancy. If these cues are not provided than the seed will remain dormant and not produce an unwanted weed to compete with the crops. In contrast, if the seed is stimulated to emerge and then the plant is killed then the soil seed bank will be depleted. Lastly, only viable seeds can produce viable offspring, therefore if the seeds or vegetative propagules are killed by predation, chemicals, diseases, or stressful environmental conditions than they will not reproduce. Seed survival varies between species and environmental conditions. Some species can survive for many years in the soil, while others cannot. Understanding the seed bank and dormancy will allow the implementation of different weed control strategies. Fallowing is an excellent way to hinder weed seed production and to deplete the soil seed bank.

Webster et al. (2003) concluded that the predominant grass species present in their study were related to either soil seedbank or a combination of soil seedbank and seed rain. They provide multiple regression equations models, which show the seedling recruitment of large crabgrass is related to the soil seedbank ($r2 = 0.44$ to 0.5), seed rain ($r2= 0.36$ to 0.41), and combination of both factors ($r2 = 0.43$ to 0.69). Pearson’s correlation coefficients show that seed rain and soil seedbank are related ($r2 = 0.41$ and 0.68). Seedling recruitment for large crabgrass was between 6% to 41% of the soil seedbank depending on year.

Stale Seed Bed

A method similar to fallowing used to control the soil seed bank is the stale seed bed. A stale seed bed is when weeds are allowed to emerge and then killed prior to planting a crop. Johnson and Mullinix (1998) defined stale seedbed as a seedbed prepared days, weeks, or months prior to seeding or transplanting a crop. They also found that shallow tillage of stale seedbeds prior to planting improved weed control in cucumber. Florida pusley and yellow nutsedge densities were lowered in plots that were tilled twice during the stale seedbed. Furthermore, shallow stale seedbed tillage coupled with a basic weed management program eliminated the need for additional herbicides for cumber production. However, Florida pusley was not effectively controlled by a stale seedbed glyphosate application made directly after cucumber seeding. The authors stated that once refined, stale seedbed offers the possibility of improving overall weed management because it does not depend on new herbicide registrations and uses commonly available equipment.

A study using stale seed bed techniques using glyphosate significantly reduced density and biomass of the principle broadleaf species (common purslane) (Caldwell and Mohler, 2001). The authors also found that a single application was just as effective as two applications of glyphosate. In essence, fallow weed control is similar to a stale seed bed because it kills emerged weeds and depletes the amount of viable seeds in the soil profile. Stale seed beds and fallowing are an important integrated weed management approach.

Lonsbary et al. (2003) found that seed bed preparation between 10-30 days before planting which was sprayed with glyphosate plus glufosinate ammonium after seeding and before cucumber emergence had higher yields than the control (0 days before planting) seedbed In addition, they found that seedbed preparation can be extended to 40 days before planting, however an application of glyphosate was needed at 20 days before planting to provide optimal cumber yields.

Herbicides Labeled for Fallowing -Post Emergence Applications

Halosulfuron-methyl

Halosulfuron-methyl (methyl 3-chloro-5-[[[[(4, 6-dimethoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]-1-methyl-1H-pyrazole-4-carboxylate is a selective herbicide used to control various broadleaves and nutsedges. This herbicide is a member of the sulfonylurea family. The mode of action is inhibiting the ALS (acetolactate synthase) enzyme in plants (Senseman 2007).

According to the label (Gowan Company) it is recommended to use a variety of cultural, mechanical, and chemical weed control techniques to avoid development of ALS herbicide resistant weeds. Cultivation should be delayed for at least 7-10 days following an application of halosulfuron. A non-ionic surfactant is recommended as an adjuvant for post emergent applications. Tank mixtures are allowed, but many have not been evaluated. Tank mixtures of halosulfuron and glyphosate plus a non-ionic surfactant are recommended to be used as a pre-plant burn down material for emerged annual grasses, broadleaf weeds, and nutsedge in sugarcane and Pioneer IR corn hybrids. A supplemental label for tank mixing halosulfuron with EPTC has been approved for use on snap beans to allow a greater spectrum of weed control. This herbicide should not be applied to stressed plants caused by drought, flooding, nutrient deficiency, disease, insect damage or other inferior growing conditions. Two sequential applications may be made per season. It is important not to exceed 0.125 pounds active ingredient of halosulfuron per acre in a single season in a fallow ground scenario. Avoiding rainfall or irrigation for at least 4 hours following a foliar application will improve efficacy. Crop maturity can be delayed due to halosulfuron applications. Halosulfuron can cause temporary yellowing and stunting of the crop as well. In the weed symptoms can be seen shortly after application. First susceptible weeds experience growth inhibition. Then the leaves and growing points become discolored. Weed death can be expected within 7 to 14 days depending on the species, size, and growing conditions of the plant. Actively growing broadleaf weeds should be should be treated at a height of 1-3 inches. Nutsedge should be treated at the 3 to 5 leaf stage. Multiple applications are needed for annual weeds that have multiple flushes of seedlings and perennials. Since halosulfuron has residual activity, time intervals between last application and planting have been established for specific crops. The time interval before planting snap beans is 2 months, cabbage is 15 months, and pepper transplants is 4 months in Florida according to the label.

Earl et al. (2004) found that gross carbon assimilation of yellow nutsedge decreased 30% compared to the pretreatment carbon assimilation rate 11 days after being treated by halosulfuron. In addition, respiration rates were significantly different than control 11 DAT when treated with halosulfuron. Halosulfuron significantly decreased the daily whole-plant water use from 6 DAT to the end of the experiment compared to MSMA, mesotrione, and the untreated plants. Shoot regrowth decreased by 95 to 100% after being treated by halosulfuron. Therefore, halosulfuron is effective at killing tubers and rhizomes of treated yellow nutsedge plants.

Halosulfuron controlled yellow nutsedge in cantaloupe production 85 to 97% at 3 and 6 WAT depending on rate and number of applications (Brandenberger et al. 2005). In a study conducted by Johnson and Mullinix (2005) halosulfuron provided 88% control of yellow nutsedge which was significantly higher than the control provided by clomazone (67% control). In addition, smallflower morningglory was controlled 86% with halosulfuron and 77% with clomazone, which was significantly different. Halosulfuron was the least injurious herbicide to cantaloupe in the trial (compared to sulfentrazone and clomazone). They also found that post transplant over the top applications of halosulfuron significantly injured transplanted cantaloupe plants. However, there was no significant cantaloupe injury when halosulfuron was applied pre plant incorporated or post direct sprayed. There were no significant differences in yields between halosulfuron, clomazone, or the untreated control. The authors concluded that halosulfuron adequately controls yellow nutsedge and many dicot weeds without injuring cantaloupes, when applied pre plant incorporated or post directed.

Nelson and Renner (2002) found that field applications of halosulfuron controlled yellow nutsedge 97%. In addition, glyphosate plus halosulfuron did not increase yellow nutsedge control and did not reduce shoot density, dry weight, or height compared to halosulfuron alone. Tuber sprouting was reduced by 19% by halosulfuron compared to the untreated control. Halosulfuron provided more than 80% reduction of tuber density and fresh weight compared to the untreated control. The authors provided several conclusions from the study. They concluded that weed control ratings late during the season were a good indicator of tuber density the following spring. In addition, tuber fresh weight and tuber density were correlated, thus the tuber density can be estimated by the fresh weight. Yellow nutsedge reproductive potential could be reduced by halosulfuron after one cropping season and long term yellow nutsedge control may be achievable by understanding tuber behavior. Yellow nutsedge control may be increased by using a pre emergence herbicide such as s-metolachlor plus a post emergent herbicide.

Glyphosate

Glyphosate (N-(phosphonomethyl) glycine) is a foliar applied non-selective systemic herbicide used to control a broad spectrum of annual and perennial grasses, broadleaves, and sedge weeds. The mode of action for glyphosate is inactivating the EPSP (enolpyruvylshikimate-3-phosphate) synthase enzyme (Senseman 2007). The function of this enzyme is to synthesize several amino acids, which are needed to make proteins for normal plant growth and development. In summary, susceptible plants treated with glyphosate experience the inactivation of EPSP, halting the production of essential amino acids, which ultimately results in plant death.

According to the label (Syngenta Crop Protection) to achieve best results apply to annual weeds 6 inches or less in height. Perennial weed control is generally more effective at the flowering or seed-head stage of growth. Glyphosate is absorbed through actively growing green plant tissue. Applying glyphosate to drought-stressed weeds, weeds with little green foliage (mowed, grazed or defoliated, etc.), dusty weeds, insect or disease damaged weeds can result is sub-optimal weed control. In the case of mowed or grazed annual weeds, allow 3-4 inches of new growth before application. In perennial weeds, allow new growth to reach the flowering or seed-head stage. The effects of glyphosate can be visibly seen in 2-4 days for annual weeds and

7 days or longer in perennial weeds. Cool or cloudy weather may delay activity. To increase the efficacy of glyphosate a nonionic surfactant or approved wetting agent should be used at a rate of 0.25% v/v (1 qt./100 gals.). In addition, ammonium sulfate may increase weed control and is recommended at a rate of 1-2% by weight (8.5 – 17 lbs./100 gals. of water). Glyphosate is labeled for chemical fallow, fallow beds, stale seedbed and post-harvest.

Application of glyphosate during the fallow period prior to planting or emergence of any labeled crop is allowed. In addition to controlling weeds during the fallow period, glyphosate can be used to kill volunteer crop plants from the previous crop, which can serve as a host to pests and diseases. In order to control problematic weeds, glyphosate can be used in conjunction with tillage in fallow systems. Tillage should be implemented no earlier than 1 day after glyphosate application and no later than 15 days after treatment. Glyphosate can be tank-mixed with oxyfluorfen herbicide for fallow use. In vegetable crops, glyphosate is labeled for broadcast application before planting transplants and before, during, or after planting but before crop emergence for direct seeded crops. Spot spraying and use as a postharvest burndown material is also allowed. It is recommended to wait 3 days after application before planting peppers. Rinse residues from plastic mulch with overhead irrigation prior to punching holes and transplanting if glyphosate is applied to fallow beds. Toxicity may occur if green treated weeds are incorporated into the soil and then the crop is immediately planted.

Clomazone, s-metolachlor, oxyfluorfen, and pendimethalin are labeled for tank mixtures with glyphosate to provide residual pre-plant/pre-emergence weed control in vegetable crops. Glyphosate does not have any soil activity. Therefore, weeds that emerge after application require a sequential application to control. Avoid application when heavy rainfall is likely to occur. It may be necessary to re-apply glyphosate if irrigation or a heavy rainfall event occurs shortly after the initial application. Wait at least 3 days before mowing or tilling the treated area to insure optimum weed control. Gylphosate is not volatile, therefore does not turn into vapor and drift after application. The label does not require any rotational crop restrictions following application.

Glyphosate can be absorbed by any vegetation including leaves, green stems, exposed non-woody roots, or fruit of desirable plants. Use higher labeled rates, application volumes, and pressures when weed vegetation is dense or large. Do not exceed 4.8 qts./A of a 5 lbs/gal material in crop areas.

Weeds with natural resistance to glyphosate are present in the wild population and repeated use of the same group of herbicides will select weeds that are resistant to glyphosate. Certain horticultural practices can be used to reduce the likelihood of developing resistance and to managing resistant weeds. To avoid herbicide resistance an integrated weed management strategy that rotates glyphosate with other types of herbicides, uses full labeled rates of glyphosate, tank mixes with other herbicides, does not allow resistant weeds to produce seeds/vegetative propagules, and monitors treated weeds for loss of efficacy should be used. Annual weeds controlled by glyphosate are, but not limited to, carpetweed, corn (not glyphosate resistant), crabgrass, crowfootgrass, cutleaf eveningprimrose, eclipta, Florida pusley, goosegrass, groundcherry, morningglory, wild mustard, black nightshade, pigweed, common purslane, redweed, southern sandbur, sicklepod, and broadleaf signalgrass. Some perennial weeds controlled by glyphosate include: bermudagrass, purple nutsedge, yellow nutsedge, and torpedo grass. Weed control results depends on herbicide rate, stage of growth, and number of applications.

Bariuan et al. (1999) conducted work with glyphosate on purple nutsedge and found that older nutsedge plants (10 weeks old) need a higher rate of glyphosate to provide the same level of control compared to younger plants (17 d old). To achieve similar levels of control 4.48 kg/ha was needed on older plants and 1.12 kg/ha was required on younger plants. A rain-free period of 72 h after glyphosate application is needed to prevent a loss in glyphosate activity. Oraganosilicone surfactant added to the tank mix did not increase glyphosate activity. Glyphosate absorption increased from 2.8% at 1 h after application to 21.4% at 168 h after application. Translocation increased from 0.43% at 1 h following application to 5.18% at 168h following glyphosate application.

Nelson et al. (2002) conducted experiments to test the effect of glyphosate on yellow nutsedge. They found that yellow nutsedge dry weight was reduced 53% with ammonium sulfate and 34% without, this was significantly different. Yellow nutsedge dry weight was not affected by spray volume. When glyphosate was injected into yellow nutsedge, plant height was reduced by 60% and control was 88%. This suggests that absorption of herbicides across the thick waxy cuticle is hindered and may limit control. Yellow nutsedge was controlled 53%, tuber density was reduced by 51%, tuber fresh weight was reduced 59% and tuber sprouting was reduced 17% by field applications of glyphosate. As mentioned, yellow nutsedge was controlled 53% 8 weeks after treatment by glyphosate and this accounted for tuber density reduction of 625 tubers/m^2 for every 10% increase in visible control. The addition of non-ionic surfactant, crop oil concentrate, and methylated seed oil with ammonium sulfate did not effect yellow nutsedge control, dry weight, tuber density, or fresh weight in the field. When glyphosate rates were increased yellow nutsedge dry weight decreased. A 50% growth reduction was observed with a 0.46 kg/ha application of glyphosate, which is 55% of the normal use rate for glyphosate.

Chachalis et al. (2001) found that glyphosate provided 83% control of smallflower morningglory in the 2-4 leaf stage and 63% control in the 5-8 leaf stage. Sharma and Singh (2007) reported that applications of glyphosate at rates of 1.25-2.5 kg/hg provided 64-76% control of Brazilian pusley and 100% control of hairy indigo. A tank mix of glyphosate plus carfentrazone provided 93-95% control of Brazilian pusley.

Siriwardana and Nishimoto (1987) concluded that to achieve the best control of purple nutsedge, with glyphosate, it should be applied when the highest number of tubers are sprouted and connected to aerial parts, because glyphosate is absorbed through aerial parts. In addition, glyphosate should be applied when the greatest portion of propagules are newly formed tubers, not corms because corms are not as susceptible. Therefore, glyphosate applications should be delayed until the end of the season right before leaf senescence appears.

Paraquat

Paraquat dichloride (1,1'-dimethyl-4,4'-bipyridinium ion) is a post emergence contact herbicide that is used for pre-plant/pre-crop emergence, chemical fallow, post emergence directed, and harvest aid desiccation in most horticultural and agronomic crops. It is used in these various situations to suppress or control grass and broadleaf weeds (Senseman 2007).

According to the label (Syngenta Crop Protection) paraquat provides good control of most small annual weeds, however perennial weeds and larger annuals especially grasses are only suppressed. Weed control may be compromised if weeds are taller than 6 inches. This herbicide is readily absorbed by actively growing green plant tissue, it interferes with the production of superoxides which results in rapid burndown symptoms in treated plants. Do not apply paraquat to drought stressed plants, mature woody stems or weeds without lots of green foliage (mowed or grazed weeds). This herbicide does not have residual soil activity, so it will not be toxic to crop plants planted after application or control weeds that germinate after application. To increase the spectrum of weed control, residual herbicides can be tank-mixed with paraquat.

Due to the rapid activity of this compound on weeds, rainfall occurring after 15-30 minutes following application will not affect weed control. A non-ionic surfactant or a crop oil concentrate is recommended as an adjuvant with paraquat. For chemical fallowing a rate of 2.5 to 4 pts per acre and a volume of at least 10 gals per acre is recommended, higher volumes may be needed for better coverage of when weed densities are high. In fallow areas paraquat can be applied immediately after harvest until crop emergence the next growing season. Paraquat may be applied twice per year on fallow land. Timing of application is crucial for this product, waiting for maximum weed emergence will increase weed control. Paraquat is effective not only at controlling weeds, but also volunteer crop plants that emerge after harvest.

Trifloxysulfuron

Trifloxysulfuron-sodium N-[[(4,6-dimethoxy-2-pyrimidinyl) amino] carbonyl]-3-(2,2,2-trifluoroethoxy)-2-pyridinesulfonamide, selectively controls broadleaves, grasses, and sedges. The mode of action for trifloxysulfuron is through the inhibition of acetolactate synthase (ALS) disrupting certain biochemical processes for essential amino acids required for plant growth (Senseman 2007).

This herbicide is labeled (Syngenta Crop Protection) for use in cotton, sugarcane, and transplanted tomato. The level of weed control is dependent on rate, type of weed, weed size, environmental conditions, and growing conditions. The efficacy of this compound is greatly improved if it is applied to small, actively growing weeds that are under favorable growing conditions. Weed control may be compromised when the soil is dry, and if weeds are large or under stress. Inhibition of growth will occur soon after application of trifloxysulfuron in susceptible weeds. The development of symptoms which occur can be characterized by plants that turn yellow, red, or purple after several days, followed by necrosis and death of the meristem. Plant death can be expected within 1-3 weeks depending on the weed species and environmental conditions.

Within the natural wild population certain species, biotypes, and individual weeds that are resistant to ALS-inhibiting herbicides may occur. Using trifloxysulfuron continuously, alone, over time can select for an increased presence of ALS-resistant weeds. In order to prevent or delay the establishment of ALS-inhibiting herbicide resistance certain weed management practices should be used. Using a rotation of herbicides that have different modes of action, effectively control the targeted weed, and are used at the full labeled rate will lessen the chance of herbicide resistance development in weeds. Cultural practices such as mechanical weed control techniques and hand weeding can help reduce the development and spread of herbicide resistant weeds.

In tomato the rotational crop interval after applying trifloxysulfuron, as measured in days, are 360 in bell pepper (transplanted), 210 for sweet corn, 90 in tomato, and 540 for all other crops for which a recommendation is not provided on the label. Trifloxysulfuron is not labeled for fallow applications, however it is labeled for post-directed and row middle weed control in transplanted tomatoes.

In addition, this herbicide is registered for early pre-plant weed control in cotton. In cotton, an early pre-plant application should be made in the fall at least 90 days before planting the crop to avoid injury. Trifloxysulfuron can be tank-mixed with paraquat or glyphosate to increase control of certain weeds when used as an early pre-plant material in cotton. Rainfall is required to activate trifloxysulfuron for soil residual control. In cotton a maximum rate of 0.0188 lbs ai/A should be used and in tomato a maximum rate of 0.0141 lbs ai/A should be used.

In tomato s-metolachlor may be tank-mixed with trifloxysulfuron for post directed sprays in transplanted tomato. Glyphosate, paraquat, and S-metolachlor can be tank-mixed with trifloxysulfuron to enhance row middle weed control in tomatoes. Generally higher rates of trifloxysulfuron should be used for larger weeds. According to the label trifloxysulfuron provides control of the following weeds: carpetweed, volunteer corn, entireleaf morningglory, ivyleaf morningglory, pitted morningglory, tall morningglory, yellow nutsedge, redroot pigweed, smooth pigweed, redweed, wild mustard, cutleaf eveningprimrose and sicklepod. Trifloxysulfuron provides suppression of purple nutsedge and Palmer amaranth according to the label. Good weed coverage is imperative for optimum weed control, this include maintaining nozzles, screens, nozzle pressure, proper sprayer calibration, agitation, and following all other labeling recommendations. A non-ionic surfactant tank-mixed with the herbicide should be used to increase efficacy of the herbicide. Applications should be made at a boom height of 15-18 inches above the top of the canopy (not the soil surface) of the intended plants. After applying trifloxysulfuron a minimum of 3 hours should pass before the treated weeds are irrigated or a rainfall event occurs to ensure that the herbicide is rain-fast.

Pre-emergence Herbicides

EPTC

EPTC (S-ethyl dipropylthiocarbamate) is a selective pre-emergent herbicide that disrupts normal germination and seedling development, it is used in multiple crops for control of many broadleaf and grass weeds. EPTC inhibits fatty acid and lipid biosynthesis (Senseman 2007).

According to the label (Gowan Company) this herbicide is intended for pre-emergent weed control, it will not effectively control established weeds. This herbicide must be incorporated, injected subsurface, or applied in the irrigation water due to its volatile nature. Incorporation of this herbicide should be done to a depth of 2 to 3 inches immediately after application to avoid loss of this herbicide. EPTC provides control of bermudagrass, crabgrass, goosegrass, field sandbur, signalgrass, tall morningglory, black nightshade, carpetweed, Florida pusley, common purslane, redroot pigweed, purple nutsedge, and yellow nutsedge according to the label. Purple and yellow nutsedge require a rate of 3 ½ pints per acre of EPTC or higher to provide effective control. Black nightshade and redroot pigweed need a rate of 4 ½ pints per acre to be effectively controlled. EPTC is label for pre-plant weed control in green beans in the southeastern United States. In the state of Florida, EPTC has an emergency registration to make pre-transplant applications on formed raised beds underneath plastic. In this type of application the herbicide does not need to be incorporated, because the plastic covering acts as a barrier to volatilization. A minimum period of 14 days after EPTC application should pass before transplanting tomatoes into the treated area to avoid crop injury. In California, Arizona, Oregon, and Idaho a 24 (c) registration has been issued to use EPTC to suppress purple and yellow nutsedge on fallow ground. For fallow nutsedge control the soil should be moist for 10 to 14 days prior to application to initiate tuber sprouting. After tuber sprouting the soil should be cultivated and EPTC should be applied and incorporated to a depth of 2-3 inches. After incorporation the soil should be leveled. Irrigation should be supplied 30 days prior to planting crops following a fallow application to avoid subsequent injury. For crops that EPTC is not labeled for a minimum of 90 days should pass before planting. A study conducted in Florida found that using EPTC as a fallow herbicide gave temporary control of purple nutsedge; excellent control 1 month after application, but not at 1 year after application (Bibhas and Wilcox 1969).

Hauser et al. (1966) found that EPTC provided better yellow nutsedge control than pebulate and vernolate. In addition the method of application affected the performance of EPTC. A subsurface soil application gave better control than spraying on the soil surface or incorporating. They found that depth of application affect EPTC efficacy on yellow nutsedge as well. A subsurface application at 1.5 in gave better control than at 5.5 in. They also evaluated application equipment and found that a power driven rotary hoe provided better control than a disc harrow for soil incorporation of EPTC. Although, EPTC provided control of yellow nutsedge they found that vernolate controlled Florida pusley better than EPTC or pebulate. In addition, peanuts were injured most by subsurface applications of EPTC.

Halosulfuron-methyl

Halosulfuron is usually applied post-emergence but it has pre-emergence activity on broadleaf weeds and sedges. According to the label (Gowan Company) moist soil is needed for pre-emergent weed control activity. This allows the chemical to dissolve and become part of the soil water solution that is absorbed by sprouting seeds or vegetative propagules and emerging seedlings. Halosulfuron can be tank-mixed with other herbicides to increase its pre-emergent activity, as well as, its effectiveness on grassy weeds. According to the label, halosulfuron has pre-emergent control of spiny amaranth, redroot pigweed, smooth pigweed, eclipta, goosefoot grass, black nightshade, horsenettle, and wild mustard. Purple nutsedge, yellow nutsedge and purslane are suppressed by pre-emergent applications of halosulfuron. Ivyleaf morningglory, tall morningglory and sandbur are not controlled by pre-emergent applications of halosulfuron.

Brandenberger et al. (2005) conducted field studies using halosulfuron pre-emergent on direct seeded watermelon. They found that applications and combinations of halosulfuron with other herbicides controlled Palmer amaranth 91 to 100% at 2 to 4 WAT and 93% to 99% at 5 to 7 WAT. Goosegrass was controlled 100% at 2 to 4 WAT and ranged from 83 to 88% at 5 to 7 WAT with clomazone plus ethalfluralin plus halosulfuron, but the authors are unsure which chemical provided control. Carpetweed was controlled 85-100% in all halosulfuron and halosulfuron plus other herbicide mixes. Control was at least 91% for all halosulfuron and tank mixes with halosulfuron for carpetweed 5 to 7 WAT except with halosulfuron alone at the lowest rate (.02 kg/ha), which provided only 64% control. All treatments containing halosulfuron controlled cutleaf groundcherry 94 to 99%. Halosulfuron applied pre-emergent will control broadleaf weeds and in combination with other herbicides will increase the spectrum of control for both broadleaf and grass weeds.

Pre-plant herbicides labeled for vegetable crops

Implementing fallow weed control techniques in conjunction with pre-plant herbicides will complement each other and enhance the overall level of weed control. Fallowing can be used to control weeds such as purple nutsedge that are not controlled very well by pre-plant herbicides. However, annual weeds that were controlled during the fallowing period can germinate, emerge, and re-infest crops after field preparation and planting. Therefore, using fallowing weed control method with tradition weed control methods is recommended.

S-metolachlor

S-metolachlor (2-chloro-N-(2-ethyl-6-methylphenyl)-N-[(1S)-2-methoxy-1-methyethyl]acetamide) is a chloroacetanilide herbicide that inhibits the biosynthesis of several plant components including fatty acids, lipids, proteins, isoprenoids, flavonoids. This herbicide seems to be involved in the conjugation of acetyl coenzyme A (Senseman 2007).

According to the label (Syngenta Crop Protection) this herbicide can be applied pre-plant surface applied, pre-plant incorporated, or pre-emergence for selective control of most annual grasses and certain broadleaf weeds in various crops including corn, pod crops, peppers, cabbage, and tomatoes. This herbicide should not be applied soils or surfaces that are prone to wind or water erosion to avoid offsite contamination. In coarse or low organic soils found in much of the state of Florida, a lower rate of the herbicide should be used. In areas with fine textured soils or high organic matter, like the muck soils in the Everglades Agricultural Area, a higher rate of S-metolachlor is needed. Some of the problematic weeds controlled by S-metolachlor which are a nuisance to production in Florida are crabgrass, crowfootgrass, goosegrass, signalgrass, yellow nutsedge, carpetweed, eastern black nightshade, Florida pusley, and pigweed. Weeds that are partially controlled by this herbicide include common purslane, eclipta, and sandbur. In this case partial control can be defined as erratic control (good to poor) or consistent unacceptable control. Poor control can be the result of dry weather following the application of S-metolachlor. To improve the efficacy of S-metolachlor it is recommended to till the soil when it is moist to kill germinating seeds and emerged weeds. S-metolachlor should be applied at planting or directly after planting. Sprinkler irrigation or rainfall should occur within 2 days of applying this herbicide. A water volume of a ½ inch is recommended for course soils and 1 inch for fine textured soils. Weed control will be compromised if adequate soil moisture is not available after application. All labeled crops may be re-planted after the current growing season following an application. S-metolachlor may be surface applied as an early pre-plant material for minimum tillage or no-tillage systems. If applications are made 30-45 days before planting a split application is recommended. Applications made less than 30 days before planting can be applied as either a split or a single application. Contact herbicides such as glyphosate and paraquat can be tank-mixed with S-metolachlor for early pre-plant usage if weeds are present at the time of application. For pre-plant surface applied, pre-plant incorporated and pre-emergence applications of S-metolachlor rate of 1 + (0.1 * % OM) pints per acre is recommended for coarse texture soils. 1.2 + (0.1 * % OM) pints per acre is recommended for early pre-plant applications of S-metolachlor on coarse textured soils. This herbicide is not intended for use on soils with greater than an 8% organic matter (OM). This herbicide can be applied as a spray solutions using water or liquid fertilizer as a carrier. S-metolachlor can be tank-mixed with other pre-emergent herbicides including clomazone, EPTC, and pendimethalin. Post emergent herbicides such as paraquat and glyphosate can be tank-mixed with S-metolachlor. In beans do not apply more than 2 pts./A per cropping year. In addition to pre-plant incorporation and pre-plant applications in transplanted tomatoes, S-metolachlor can be applied on the soil surface to raised pressed beds prior to laying plastic (underneath the plastic) in plasticulture production systems. In tomatoes do not make applications within 90 days of harvest. Injury can be reduced in tomatoes if the herbicide application is made 7 or more days before transplanting.

McNaughton et al. (2004) conducted research on the effect of various herbicides on snap beans in Canada. They found that s-metolachlor applied pre emergence did not cause significant visual snap bean injury at any rate for both years of the study. In addition, plant height was not reduced by pre emergence applications of s-metolachlor. Also, snap bean yields were not reduced compared to the untreated check when s-metolachlor was applied pre emergence.

Clomazone

Clomazone (2-(2-Chlorophenyl)methyl-4, 4-dimethyl-3-isoxazolidinone) is an herbicide used for pre-emergent control of weeds in succulent beans, cabbage, cucumbers, watermelon, muskmelon, succulent peas, peppers, squash, sweet potatoes and other tuberous and corm vegetables. Evidence suggests that clomazone is metabolized its active 5-keto form. The 5-keto form inhibits DOXP (1-deoxy-D-xyulose 5-phosphate synthase), which is a crucial component to plastid isoproprenoid synthesis (Senseman 2007).

According to the label (FMC Corporation Agricultural Products Group) it can be applied before seeding or transplanting and after seeding but before crop emergence. It is important to plant seeds and transplant roots below the chemical barrier at planting. Clomazone causes bleaching symptoms and death to treated plants. Clomazone can be used 30 days before planting the crop until just prior to crop emergence. In peppers (excluding banana peppers) a rate of 0.67 to 2.67 pints per acre is recommended. A lower rate is recommended for coarse soils. One application may be made per season. According to the label at rate of 2 pints per acre (0.75 lbs. a.i.), clomazone provides control of the following weeds; broadleaf signal grass, large crabgrass, goosegrass, purslane, and redweed. At a rate of 2.67 pints per acre (1 lb. a.i.), the same weeds as 2 pints are controlled plus; field sandbur and Florida pusley. Peppers can be planted at anytime after an application of clomazone at the same rate. At the same rate of 1 lb a.i. per acre beans, direct seeded cabbage, transplanted cabbage, and transplanted tomatoes can be replanted 9 months after the initial application. Sweet corn and direct seeded tomato can be planted 1 year after application. All other crops can be planted 16 months after application.

Johnson and Mullinix (2005) concluded that clomazone is safe to cantaloupe and controls many annual weeds, however it does not adequately control yellow nutsedge and smallflower morningglory. Lonsbary et al. (2003) reported that plots that were treated with clomazone pre-emergence had higher cucumber yields than the untreated control.

Pendimethalin

Pendimethalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine) causes mitotic disruption by inhibiting the microtubule protein tubulin (Senseman 2007). Pendimethalin interferes with the weed’s cellular division (mitosis) in the meristematic regions.

Accoding to the label (BASF Corporation Agricultural Products) pendimethalin can be used for the following vegetable crops: carrots, corn, edible beans, garlic, lentils, peas, mint, onions, dry bulb shallots, and potatoes. This herbicide is used to control most germinating annual grasses and certain broadleaves. Low rates of pendimethalin should provide control of crabgrass, crowfootgrass, field sandbur, signalgrass, Palmer amaranth, carpetweed, pigweed species, purslane, and Florida pusley according to the label. If resistant weeds are present or develop over time to meristematic inhibiting herbicides than an herbicide with a different mode of action should be used in rotation. Pendimethalin is most effective when it is incorporated into the upper soil surface by rainfall, irrigation, or tillage before weeds emerge from the soil. This herbicide can be applied on the surface pre-plant, pre-plant incorporated, surface incorporated, pre-emergence, early post-emergence, post-emergence incorporated or layby treatment. Pre-plant surface applications can be made up to 45 days before planting. Pre-emergence applications can be made at planting and up to 2 days after planting. Pendimethalin does not kill established weeds, so tillage before application is crucial. At a rate less than 2 lbs ai/A all crops that are labeled can be replanted within the same season of application. Crops that are not labeled for use with pendimethalin cannot be planted until a year after the initial application at the same rate. In edible beans, pendimethalin can be used as pre-plant incorporated material for chickpeas, dry beans, lima beans, snap beans, and cowpeas. Pre-plant incorporation applications can be made up to 60 days before planting. Pendimethalin can be applied either pre-plant incorporated or pre-emergence in sweet lupines. Pre-emergence applications should be made at planting or up to 2 days after planting in a seedbed that is free of clods. In southern states with a course texture soil a rate of 1.5 pts/A is recommended for use on edible beans. Pendimethalin has a supplemental label that allows it to be used as a pre-plant incorporated or a pre-plant surface material before planting tomato and pepper transplants, or as a post-directed spray to transplants or established direct seeded plants. In addition, this herbicide has a supplemental label for use on strawberries, refer to the label for specific information.

Oxyfluorfen

Oxyfluorfen (2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene) provides both pre-emergence and post-emergence weed control. The mode of action is to inhibit the enzyme PPO or Protox (protoporphyrinogen oxidase) (Senseman 2007).

According to the label (Dow AgroSciences LLC) this herbicide is registered for use on broccoli, cabbage, cauliflower, fallow bed, horseradish, mint and onions. Oxyfluorfen provides control of spiny amaranth, carpetweed, large crabgrass, cutleaf eveningprimrose, cutleaf groundcherry, annual morningglory species, wild mustard, American black nightshade, redroot pigweed, common purslane, Florida pusley, and sicklepod. This herbicide is labeled for pre-transplant applications in broccoli, cabbage, and cauliflower. This herbicide should be applied after field preparation but before transplanting. Minimizing soil disturbance when planting will result in better weed control performance.

Temporary initial leaf cupping or crinkling may occur in treated transplants, but the crop will outgrow this response and develop as normally. This response will be lessened if the crop leaves are not allowed to come into contact with the soil. This response may be amplified by stressful conditions from temperature, disease, fertilizer, nematodes, insects, pesticides, or storage conditions. Extremely succulent transplants may be more prone to develop severe injury. Older, hardened off transplants grown in bigger cell sizes will decrease the chances and/or degree of crop injury. The recommended rate for oxyfluorfen is 0.25 to 0.5 lbs active ingredient per acre. The lower rate is recommended for course textured soils with lower than 1% organic matter. Severe crop injury can result from using oxyfluorfen and an acetanilide herbicide (S-metolachlor) during the same cropping season. According to the label the weeds controlled in cabbage at the recommended rate are carpetweed, redroot pigweed, common purslane, and Pennsylvania smartweed. Oxyfluorfen may provide partial control of wild mustard. It is recommended to apply this herbicide with ground spray equipment with flat fan nozzles at a pressure of 20 to 40 pounds per square inch (psi). Applying a rate of oxyfluorfen higher that 0.5 lbs active ingredient per acre per season is prohibited.

Oxyfluorfen is not approved for use on direct seeded or green house grown cole crops. In addition to being labeled for cabbage, broccoli, and cauliflower, oxyfluorfen is labeled for use on fallow beds. In fallow beds, oxyfluorfen is used as a pre-emergent or post-emergent herbicide, it can be used alone or mixed with glyphosate to control winter annual broadleaf weeds. In direct seeded legume vegetables 60 days should pass after application before planting in a treated fallow bed. When oxyfluorfen is applied on a fallow bed at a rate of 0.5 lbs active ingredient per acre broccoli, cabbage, cauliflower, garlic, onion, pepper, strawberries, and tomatoes should not be planted until 30 days after treatment. Treated fallow beds should be cultivated to a depth of at least 2.5 inches before planting. At a rate of 0.5 lbs active ingredient per acre oxyfluorfen should provide pre-emergence weed control for 8 weeks to susceptible species and post emergence control of these weeds until the 6 leaf stage. Irrigation or rainfall needs to occur within 3 to 4 weeks following application to obtain the best weed control results. As mentioned earlier, a tank mixture with glyphosate will improve the efficacy of post emergent weed control. A maximum rate of 0.5 lbs active ingredient pre acre per fallow season is allowed. In California, oxyfluorfen is labeled for use on fallow beds before transplanting strawberries and peppers using plasticulture. This herbicide should be applied to the moist soil of preformed beds prior to covering with plastic. A minimum of 30 days should pass before transplanting peppers or strawberries into the treated area.

General factors effecting herbicide efficacy

Weed species, size, infestation intensity, and growth stage have a profound effect on herbicide activity. Younger plants are easier to control than older plants. Herbicides are more effective on smaller plants than bigger plants and it is better to apply herbicides to weeds in their vegetative state than in their reproductive phase. Foliar herbicides will not kill mature seeds on the plant. In addition, foliar herbicides are absorbed through green tissue, so mature plants with woody stems are more difficult to control and require different types of herbicides to control. Herbicide rate, surfactants, number of applications, time of exposure, and environmental factors will affect the efficacy of the herbicide. In general higher rates provide greater control up to a certain level. Older nutsedge plants (10 weeks old) need a higher rate of glyphosate to provide the same level of control compared to younger plants (17 d old). To achieve similar levels of control 4.48 kg/ha was needed on older plants and 1.12 kg/ha was required on younger plants (Bariuan et al. 1999).

Surfactants can increase herbicide uptake in many weed species. Surfactants potentially increase herbicide activity by maximizing the surface area of the spray droplet and degrading waxy cuticles or allowing herbicide penetration into woody stems. Oraganosilicone surfactant tank-mixed with glyphosate did not increase activity on purple nutsedge (Bariuan et al. 1999). One herbicide application may provide adequate weed control and sometimes multiple applications are needed. This varies depending on the herbicide and the weed species. Longer exposure times will facilitate herbicide absorption to a certain extent. Achieving a threshold concentration of herbicide within the plant will provide the desired weed control. Optimizing the time of herbicide exposure to the plant will increase herbicide activity. This can be done by applying herbicides on a sunny, rain-free day. A rain-free period of 72 h after glyphosate application is needed to prevent a loss in glyphosate activity on purple nutsedge (Bariuan et al. 1999). Environmental factors such as light, soil moisture and temperature will affect herbicide activity. Since herbicides are absorbed by actively growing plants, environmental stresses that negatively impact the growth of the plant will hinder herbicide uptake and performance. Herbicide absorption and translocation can continue to occur even a week after application. Glyphosate absorption in purple nutsedge increased from 2.8% at 1 h after application to 21.4%

at 168 h after application. Translocation increased from 0.43% at 1 h following application to 5.18% at 168 h following glyphosate application (Bariuan et al. 1999). However, if an herbicide is sufficiently taken up, translocated, and then an environmental stress such as drought occurs this can increase the herbicide activity on the plant. Basically, a healthy plant is better adapted to overcome stress than a sick plant.

Herbicide activity on crops

The ultimate goal of applying an herbicide is to reduce weed competition to achieve higher crop yields and or quality. Herbicides are not equally effective against all weeds. Selecting an herbicide should be tailored to reduce the historic and present weed populations in a given field. In addition, not all crops react positively when herbicides are applied. Therefore, herbicides that either harm the crop or are not economically beneficial should not be used in a given production system. Crop toxicity to herbicides can be dependent on herbicide type, rate, method of application, tank mixtures, environmental conditions, residual activity of herbicide, and duration after application before planting.

Previous fallow work

Cools and Locascio (1977) found that applications of glyphosate provided a significantly linear decrease in purple nutsedge count density as the application rate increased. A second application of glyphosate further reduced nutsedge compared to a single application. At a rate of 1.12 kg/ha one application decreased nutsedge 66% and two applications provided 95% control. Glyphosate applied in the summer or in the fall provided good control. However, multiple applications of summer and fall or spring, summer, and fall provided excellent control. The spring treatment had the poorest control compared to the other treatment seasons. Spring applications had poor nutsedge control due to tuber dormancy related to cooler soil temperatures.

Germination of tubers do not occur at soil temperatures below 14C and germination rate increases with temperature. Even the untreated control had a low nutsedge density.

Independent of treatment season, all glyphosate treatments provided significantly lower nutsedge populations 2 to 5 months after the final application. One application was not different than two applications made a week apart within a single season, except for in the spring. In the spring this was attributed to fact that nutsedge had a longer time to emerge between treatments. The best control was provided by two applications made in consecutive seasons of summer and fall. Cools and Locascio (1977) indicated that further may show that the time between applications can be shortened.

Edenfield (2000) found that fallow applications of glyphosate at 1.14 kg/ha provided better purple nutsedge control than the 0.57 kg/ha rate. In addition, sequential applications at the same rate to the same sized plants tended to provide higher purple nutsedge control than single applications. They found mixed results regarding the efficacy of glyphosate on purple nutsedge between small (8-15 cm) and large sized (20-30 cm) plants. The purple nutsedge populations in the untreated checks increased in numbers throughout the years of the study. These results are consistent with the findings made by Cools and Locascio (1977).

Brecke, et al. (2005) conducted an experiment using various herbicides to control purple nutsedge in a bare ground field, homogeneously infested with purple nutsedge. They discovered that >80% control of purple nutsedge shoots was achieved by sequential applications of halosulfuron applied early post emergence followed by late post emergence at a rate of 70g/ha; this was not significantly different than a single early post emergence application.

Another herbicide that was tested during that experiment was s-metolachlor. S-metolachlor applied pre emergence at a rate of 4,480 g/ha provided 75% control of purple nutsedge shoots. S-metolachlor applied pre emergence provided control of foliage, and reduced total density and viability of purple nutsedge. Total tuber density was reduced by an average of 50% and tuber viability was reduced by an average of 59% by halosulfuron. They speculated that the control of shoot biomass by mowing or herbicide applications (even if they are not translocated) may cause the depletion of total tuber number and viability by decreasing carbohydrate reserves. In the same trial, weekly mowing increased purple nutsedge control from 60% compared to non-mowed and 66% across all herbicides. Thus mowing increased purple nutsedge shoot control and may enhance control when used with herbicides.

Smith and Mayton (1938) and Smith (1942) and found that frequent tillage applied every 3 weeks over a two year period resulted in the eradication of purple nutsedge in fields on more than 10 types of soil. According to Webster (2003) infrequent tillage may have the opposite effect as frequent tillage on purple nutsedge populations. Explaining that it may be possible that infrequent tillage can serve to fragment tuber chains, release apical dominance and ultimately increase the number of purple nutsedge. Webster states that a key to managing purple nutsedge with herbicides is to apply when the maximum number of shoots are emerged, which is dependent on warm soil temperatures. He summarized herbicides used to control purple and yellow nutsedge based into 3 categories: soil activity only, foliar activity only, and both soil and foliar activity. The effectiveness of these herbicides were documented in the paper. Metolachlor a soil applied pre emergence herbicide provided 55 % to 85 % control of yellow nutsedge and less than 20 % control of purple nutsedge. Glyphosate a foliar applied post emergent herbicide provided 55 % control of yellow nutsedge and 70 % control of purple nutsedge. Halosulfuron and trifloxysulfuron provide both soil and foliar activity. Halosulfuron provided 85 to 95 % control of both yellow and purple nutsedge. Trifloxysulfuron provided 75 to 95 % control of yellow nutsedge. The amount of purple nutsedge control provided by trifloxysulfuron was unknown. The effectiveness of these herbicides is dependent of weather conditions. Conditions favoring growth results in improve nutsedge control. While dry conditions often reduce nutsedge control. Lastly, he concluded that nutsedge control is a multi-season effort and that long-term control will require management strategies that reduce or eliminate tuber production and viability.

CHAPTER 2
FALLOW EXPERIMENT - LIVE OAK, FL LOCATION

Objective

The objective of this study was to effectively and economically reduce the weed population during fallow periods before a vegetable crop is planted. Weeds such as nutsedge, which are hard to control once the crop is planted was of particular interest, especially due to the phase out of methyl bromide.

Materials and Methods

The experiment was conducted in Suwannee Valley Research and Education Center in Live Oak, FL to investigate several fallow treatments on weed control. The soil type at this location was a Blanton-Foxworth-Alpin Complex. The fallow experiment was a 2 x 3 factorial established in a randomized complete block design with 4 replications. The two factors examined were; mechanical control and chemical control. The mechanical control was no till and tillage. The chemical control consisted of; no herbicides, glyphosate and glyphosate plus halosulfuron-methyl. The treatments consisted of combinations of these two factors for a total of six treatments which include no till/no herbicide, no till/glyphosate, no till/glyphosate plus halosulfuron-methyl, tillage/no herbicide, tillage/glyphosate, and tillage/glyphosate plus halosulfuron-methyl. The dimension of each experimental unit or plot was 15 x 60 feet.

All herbicides were applied using a CO_2 pressurized backpack sprayer operating at a pressure of 30 PSI at an application rate of 30 gallons per acre. During application the boom was held 18 in above the target weeds. Glyphosate was applied at 1.25 lbs ai/A. Halosulfuron-methyl was applied at 0.05 lbs ai/A, this was tank mixed with glyphosate at the previously mentioned rate. All herbicide treatments contained a non-ionic surfactant (NIS) at a rate of 0.25

% volume/volume. Two weeks after applying herbicides the tillage treatments were rototilled to a depth of 4 inches.

Year 1 - Fallow

The experiment was conducted in a field that had been out of horticultural production for some time. The entire field was tilled prior to the experiment. Emerging weeds within the area were evenly distributed throughout the field. All weed density measurements were made by randomly tossing a 0.5 m^2 rectangle made of PVC pipe and counting the weed population within the perimeters of the rectangle. Initial weed density measurements were taken on 24 July, 2006. These weed density measurements were performed by making six random measurements within the experimental area. The counts for each individual weed species were then averaged across all measurements and were used as a representation for the weed population density for the entire field. The first chemical fallow treatments were applied on 26 July, 2006. The weed counts after all the first treatments were applied were taken on 21 September, 2006, except for the control plots which were assumed to contain the same weed density as the initial weed counts. These weed counts were made by randomly measuring one representative sample per treatment. The second herbicide treatments were applied on the same day as the weed counts (21 September, 2006). Two weeks later the second tillage treatments were applied. The treatments were visually rated after the second treatments were applied. Weed counts were taken on 30 March, 2007 prior to the preparing the field for the spring crop. Two measurements representative of the population were taken per plot before planting in the spring.

Year 1 - Crop

Initial intentions were to plant a crop in the fall; however it was too late in the season so it was decided to plant in the spring. In the spring the field was shank fumigated with C-35 Telone at a rate of 26 gal/A for nematode control on 8 February, 2007. The field was then rototilled from north to south across all treatments on 7 March, 2007. The field was rototilled north to south again and the beds were formed for the peppers on 4 April, 2007. The beds were formed across the width (15ft) of the plots and intercepted all treatments areas. Metolachlor was applied as a pre-plant, pre-emergent herbicide on 5 April, 2007. Two rows of black polyethylene mulch were laid across the beds following the metolachlor application on the same day. Bell pepper transplants were planted on 11 April, 2007 and irrigated with an overhead sprinkler gun to get established. The peppers continued to receive overhead irrigation throughout the growing season. In addition to overhead irrigation the peppers also received drip irrigation/fertigation starting on 4 May, 2007. In addition to peppers, 4 double rows of snap beans were planted with a Monosem 2 row vacuum planter on 18 April, 2007. The snap beans were watered solely with overhead irrigation during the fist year. The snap beans were side dressed with 300 lb/A of 13-4-13 fertilizer which provided 36 lbs of nitrogen on 25 May, 2007 and 8 June, 2007. A visual diagram of the experimental design is depicted in Figure 1-1.

The crops were sprayed regularly on a weekly basis starting on 20 April, 2007 and ending on 21 June, 2007. The weekly crop sprays consisted of 1) Penncozeb (2.5 lb/A) or Manzate (2.0 lb/A), 2) Kocide 4.5 LF (2 pt/A), and 3) Spintor (6 oz/A) or Endosulfan (1.3 qt/A) or Permethrin (8 oz/A). The crops were burned down with paraquat (Gramoxone) at a rate of 2 pt/A on 1 July, 2007. The plastic mulch was removed and the plot was harrowed on 9 July, 2007.

All in-row (within the black plastic mulch bed) weed counts were taken for the entire length of both rows within each treatment, since the plots are 15 ft wide and there are 2 rows, this results in 30 linear bed ft of black polyethylene mulch per treatment. In-row purple nutsedge counts were measured on 23 April, 2007 and 2 May, 2007, since it was the only weed to emerge at the time. All in-row weeds were counted on 16 May, 2007; this includes purple nutsedge that penetrated through the plastic mulch and the weeds that emerged within the pepper planting holes. There was only one row middle since there were only two rows. The row middle weed counts were measured by taking one 0.5 m^2 sample directly in the middle of the plot. Pepper row middle weed counts were taken on 22 May, 2007. The heights of six pepper plants per plot were randomly measured with a ruler in cm on 23 May, 2007, to determine if any of the herbicides stunted the crop. Percent check ratings and weed counts were measured in the snap beans on 30 May, 2007. Deer damage was observed during the first cropping season in both the bell peppers and the green beans. Pepper harvests were taken from 5 plants in each row, making 10 harvested plants per treatment. The first pepper harvest was conducted on 13 June, 2007 and only marketable fruits were picked. The peppers were harvested a second time on 28 June, 2007 and all fruits were harvested regardless of size unless they were physically damaged (blossom end rot, sun spots, eaten by insects/animals, etc.). Fruit weights (in lbs) were recorded for both pepper harvests in each treatment.

Year 2 - Fallow

The fallow during the second year was conducted the same as the first year, except the weeds were recounted in the untreated controls every sampling date. The reason the initial untreated counts were taken repeatedly is because weeds such as nutsedge continue to propagate and multiply in number during the summer, especially when no treatments were applied. Furthermore, weed populations fluctuate up and down during the fallow period due to weather conditions, independently of the treatment effects. Therefore, recording the untreated control counts during every sampling date provides a better contrast than when compared to using the weed population encountered at the beginning of the fallowing period as a base level. In addition, unlike year one, weed counts were made after each spray application and cultivation event, instead of one measurement after both were implemented.

During the second year the fallow treatments were applied to the same exact areas as the previous year. The permanent metal stakes marking the boundaries of the treatment areas allowed identification of the plots even after the first year's crop was tilled under. However, the fallow treatments were modified slightly the second year, due to timing constraints. Halosulfuron was only applied with glyphosate during the first spray application. The second spray applications consisted solely of glyphosate for all herbicide plots. The reason halosulfuron was applied only once is because the minimum pre plant interval criteria could not be met between a late summer fallow application and a fall planting. In addition, cultivation was performed once the second year instead of twice. It would have been impossible to cultivate and wait for weed emergence before planting without planting too late during the fall. The rationale behind having a fall crop was to contrast differences in weed spectrum, infestation severity, crop yields and responses to summer fallowing between growing seasons.

Initial fallow weed counts were taken from two locations per plot on 4 August, 2007. The first herbicide treatments were applied on 13 August, 2007. The effects of the herbicide were allowed to take place and weed counts were taken on 24 August, 2007. The cultivated plots were rototilled on 25 August, 2007. Following cultivation and weed emergence, weed counts were measured on 14 September, 2007. Glyphosate was applied to the herbicide treatment plots on 15 September, 2007. After the effects of the herbicides were allowed to take place weed counts were recorded on 27 September, 2007. It was not possible to obtain weed counts from the untreated plots at this time due to the overwhelming size of the plants, therefore the counts from the previous weed count incidence was used. The entire field was then cultivated to prepare for planting.

Year 2 - Crop

During the second cropping season bell peppers were planted on black plastic mulch and snap beans on bare ground to replicate the previous year's experiment. In addition, cabbage was planted during the second year on bare ground. Planting was delayed further than expected and thus cabbage was selected for its ability to survive winter frosts. These crops were chosen not only because they would contrast between weed control on plastic mulch vs. bare ground, but because these crops differ in sensitivity towards halosulfuron carry-over. Another reason these crops were chosen was because different pre-plant/pre-emergence herbicides are labeled for these crops and we were interested in finding fallow/pre-plant herbicide combinations that would be best for controlling specific weeds in each of these crops. In the first cropping season s-metolachlor did not adequately control weed emergence in peppers and in snap beans. Therefore, in the second year in addition to s-metolachlor more pre-plant/pre-transplant/post-transplant/pre-emergence herbicides were included in the trials to all of the crops. The second year crop was a split plot design were the fallow blocks were the main plots and the different pre-plant herbicides were the subplots. Inconsistencies in uniformity were observed using the single water gun to irrigate overhead because of the layout of the field (distance from the water gun), leaking near the sprinkler head, and wind blowing water away. To solve this problem, drip irrigation was used for all the crops.

In peppers, the pre-transplant treatments consisted of an untreated control (no herbicide), s-metolachlor (7.62 lbs a.i./gal material at a rate of 1 pt /A), clomazone (3 lbs a.i./gal material at a rate of 2.5 pt/A), and EPTC (7 lbs a.i./ gal product at an application rate of 3 pt/A) . These herbicides were all applied to the soil surface after bed formation, immediately covered by plastic mulch, and remained undisturbed for 7 days prior to planting the pepper transplants. All chemicals are currently labeled or are being evaluated for pre-transplant underneath the plastic on bell peppers and the 7 day waiting period before planting was implemented in accordance with the EPTC restrictions to prevent phytotoxicity. The snap beans pre-emergence herbicide treatments included an untreated control, s-metolachlor (7.62 lbs ai/gal at 1 pt/A), EPTC (7 lbs a.i./gal at 4 pt/A), and pendimethalin (3.8 lbs a.i./gal at 1.5 pt/A). EPTC was applied before planting the beans and was incorporated to a depth of 2 inches using shallow tillage to prevent volatilization. The beans seeds were then planted in a single row using a mechanical planter. After planting, s-metolachlor and pendimethalin were applied to the soil surface prior to bean emergence. In the cabbage, the pre plant herbicide treatments were an untreated control, s-metolachlor (7.62 lbs a.i./gal at 1 pt/A) and oxyfluorfen (4 lbs a.i./gal at 1pt/A). The oxyfluorfen was applied pre-transplant and the s-metolachlor was applied post-transplant over the top.

In the peppers both purple and yellow nutsedge that penetrated the plastic or emerged through the planting hole were counted in each sub-plot, which ran the width of the plot (15 LBF). In the cabbage and snap beans visual weed control ratings of each weed were taken in each subplot. The only exception was purple and yellow nutsedge which were rated within the main fallow plots since the pre-treatments did not have such a profound effect as the fallow treatments. The ratings were percentage weed control, meaning a rating of 0 correlates no control and 100 correlates total eradication of that particular weed.

The first frost occurred before the bell peppers and the green beans were ready to harvest. The peppers were at first flower and the snap beans had begun to flower when they were killed by the freeze. Since harvesting mature fruits were not an option, we harvested the plants and took dry weights. On 3 December, 2007 five pepper plants and 1m row of bean plants were cut at ground level, placed in labeled paper bags, and dried in a drying room. The plant samples were weighed and recorded in grams. The cabbage was harvested on February 12, 2008 by hand, the number of heads per subplot and the total weight in lbs were recorded.

Statistical Analysis

Data was analyzed using the PROC GLM procedure in SAS. Significance was established based on the analysis of variance and the means were separated using least significant difference procedure. When analyzing the fallow weeds the initial counts were not included in the ANOVA model, since the counts were taken before the treatments were applied. Factors that had a significant effect were analyzed using LSD means separation. Furthermore, combinations of the factors were analyzed using one way ANOVA and means were separated using LSD as described by Marini (2003). This was done to compare the effect of factorial combinations with the untreated check.

Results and Discussion

Fallow Period

Purple nutsedge fallow

Purple nutsedge was evenly distributed throughout the trial. A clear separation in nutsedge counts between herbicide treatments (0-8 nutsedge/m2), the untreated control (15-39 nutsedge/m2), and the cultivated control (24-78 nutsedge/m2) was seen after the second fallow treatment and throughout the rest of the fallow period (Figure 1-2). At least two consecutive herbicide treatments may be needed to effectively lower the nutsedge population.

There were no differences in purple nutsedge counts before fallow applications were applied or following the first fallow applications. The effect of herbicides on purple nutsedge counts were significant after the second fallow treatment applications were made. The effect of herbicides on purple nutsedge counts continued to be significant throughout the rest of the fallowing period. Both glyphosate and glyphosate tank mixed with halosulfuron reduced purple nutsedge numbers (0 to 5.88 nutsedge/m2) compared to the non herbicide treated plots (19.5 to 54.63 nutsedge/m2) during this period (Figure 1-3). In addition, there was an interaction in purple nutsedge counts between cultivation and herbicide treated plots on the last sampling date of the fallow period during the second year. On the last sampling date, the cultivated check plots contained the highest amount of purple nutsedge. The untreated check plots (28 nutsedge/m2) contained less purple nutsedge than the cultivated check plots (78.25 nutsedge/m2) (Figure 1-4). All the herbicide treated plots contained less purple nutsedge (0 nutsedge) than the untreated check (28 nutsedge) except for glyphosate combined with cultivation (2.25 nutsedge).

The increase in purple nutsedge by cultivation can be explained by two factors. First, cultivation breaks up the intricate system of underground tuber chains, releases the dormant tubers from apical dominance, and induces tuber sprouting. In addition, cultivation reduces most of the weeds that are propagated by seed and therefore reduces interspecific competition for weeds that are propagated vegetatively that are not controlled by tillage, such as purple nutsedge. However, these results are contrary to the results found by others, where cultivation controlled purple nutsedge by depleting the carbohydrate reserves within the tubers, and desiccating the tubers which caused them to die. The difference was that the tillage in these experiments was done repeatedly, which did not allow purple nutsedge to reestablish, flourish, and continue to propagate. Another reason that would explain the inconsistencies between past experiments was the fact that tillage during dry seasons caused purple nutsedge tubers to desiccate and die, however in this experiment cultivation was performed during the Florida summer wet season. In essence, cultivation would be more promising to effectively control purple nutsedge when performed routinely and during the dry season. Implementation of cultivation to control purple nutsedge in Florida during the summer fallow period, may not be economically or logistically feasible.

Glyphosate and glyphosate plus halosulfuron provided excellent purple nutsedge control. They are known to translocate throughout the plant and destroy the underground portions of nutsedge. Since glyphosate alone provided excellent control in our experiment (better than expected) the addition of halosulfuron may not be needed to increase purple nutsedge control.

Yellow nutsedge

The experimental field was uniformly covered with a high number of yellow nutsedge at the beginning of the trial (73 yellow nutsedge/m2) (Figure 1-5). After only one fallow treatment was applied the numbers of yellow nutsedge were dramatically reduced compared to the untreated control. Furthermore, cultivating and/or herbicides reduced the number of yellow nutsedge compared to the untreated control throughout the both fallowing seasons.

Analysis of variance indicated that there was a significant interaction in yellow nutsedge counts between herbicide and cultivation.. The reduction in yellow nutsedge counts was significant after the first fallow treatment was applied (Figure 1-6). All fallow weed control methods reduced yellow nutsedge (0.5 to 6.5 yellow nutsedge/m2) compared to the untreated control (73 yellow nutsedge/m2). Compared to purple nutsedge, yellow nutsedge was relatively easy to control. Yellow nutsedge does not have an extensive system of multiple underground tubers on rhizome chains, but instead only has one terminal tuber per rhizome. This difference in morphological structure is likely the reason why yellow nutsedge is controlled by either tillage or herbicides after only one fallow treatment.

Florida pusley fallow

The initial counts of Florida pusley were similar for all treatments. After the third fallow treatment (first treatment of the second year), a pattern in Florida pusley counts starts to emerge between the untreated control, cultivated control, and herbicide plots that continues for the remaining fallow period (Figure 1-7). The untreated plots contained the highest pusley counts (138 – 270 pusley/m2), the cultivated check had a moderate amount of pusley (49 – 164 pusley/m2) and the herbicide plots had the least amount of pusley (0.25 – 15 pusley/m2).

There were significant differences in pusley counts due to fallow herbicides. After the second fallow treatment and throughout the rest of the fallow period the counts in untreated plots ranged between 29 to 224 pusley/m2 and were higher than in either herbicide plot which ranged between 4 to 79 pusley/m2 (Figure 1-8). There were no significant differences in pusley counts between areas treated with glyphosate or glyphosate tank-mixed with halosulfuron.

There were significant differences in pusley counts between cultivation methods. After the first fallow treatments were applied pusley counts were higher in the cultivated plots (205 pusley/m2) than in the non-cultivated plots (84 pusely/m2) (Figure 1-9). Although, tillage killed the majority of the existing pusley plants, it stimulated a flush of pusley seeds within the soil to germinate in synchronization. However, after the third fallow treatment the non-cultivated areas had significantly higher pusley counts. Therefore, it appears tillage over time gradually depletes the soil seed bank reserves and limits the seed rain being deposited within the soil. The pusley counts in the uncultivated plots were 162 pusley/m2, compared to the cultivated plots which had an average of 91 pusley/m2.

Crabgrass fallow

Initially crabgrass was uniformly distributed throughout the field. However, after the first fallow treatments were applied, all methods drastically lowered the crabgrass infestation compared to the untreated control (Figure 1-10).

The interaction in crabgrass counts was significant between cultivation and herbicides. The amount of crabgrass reduction ($\geq$ 86 %) was significant compared to the untreated control

(74 crabgrass/m2), after just one fallow application (Figure 1-11). Glyphosate tank mixed with halosulfuron without cultivating (2 crabgrass/m2) controlled crabgrass better than the herbicide combination plus tillage (11 crabgrass/m2) and cultivation alone (9 crabgrass/m2). Furthermore, spraying glyphosate without cultivating (3 crabgrass/m2) reduced crabgrass to a greater extent than spraying with glyphosate plus halosulfuron with cultivation (11 crabgrass/m2). Although tillage controlled the existing crabgrass population, it stimulated new crabgrass seedlings to germinate. On the other hand, herbicides controlled emerged crabgrass but did not disturb the soil and cause seedling germination. Halosulfuron does not control grasses, therefore it was not expected to increase the efficacy of glyphosate.

Similarly, there were significant differences between treatments at the beginning and after the first fallow application of the second year. There was long term carry over control from the previous year's fallow treatments at the beginning of the second year. Cultivating alone (5 crabgrass/m2) and all the herbicide treatments (1.75-2.25 crabgrass/m2) except halosulfuron tank mixed with glyphosate without cultivation (9 crabgrass/m2) reduced crabgrass counts compared to the untreated control (11 crabgrass/m2).

After the first round of herbicides were applied the second year the untreated check had the highest crabgrass densities (20 crabgrass/m2), followed by the cultivation check (9 crabgrass/m2) and then all fallowing techniques that utilized herbicides (0-0.75 crabgrass/m2). In general cultivation provided better crabgrass control than non cultivation fallowing regiments. In addition, fallowing using glyphosate or glyphosate plus halosulfuron reduced crabgrass infestation better than non-herbicide programs. Cultivation and the herbicides killed adult crabgrass, which prevented seed production and caused a decline in the population. As expected, halosulfuron did not increase the efficacy of glyphosate.

Hairy indigo fallow

There was a separation in hairy indigo counts between the untreated, cultivation alone and herbicide plots (Figure 1-12).The untreated plots contain the highest number of hairy indigo, the cultivation check plots have a moderate amount of hairy indigo and the plots treated with either glyphosate by itself or tank mixed with halosulfuron had the lowest density of hairy indigo. Glyphosate alone or tank mixed with halosulfuron consistently provided excellent control of hairy indigo. Although cultivation controlled adult hairy indigo plants, it could have induced germination by scarifying the hard seed coat, allowing the seed to imbibe water and break physical dormancy.

There was a significant difference in hairy indigo counts between herbicide treated plots. After the second fallow treatments were applied until the end of the fallow period, the non-herbicide treated plots contained more hairy indigo (21to 24 hairy indigo/2) than the herbicide treated plots (0 to 11 hairy indigo/m2) (Figure 1-13).

Browntop millet fallow

The cultivation without herbicide plots consistently had a greater number of browntop millet compared to the infestation found in all the other treated plots and the untreated check (Figure 1-14). A likely explanation, is that tillage scarified the seed husk surrounding the browntop millet seed, released the seeds from dormancy, and promoted germination.

In the beginning of the second year there was an interaction between cultivation and herbicides. The cultivated check contained more browntop millet (20 browntop millet/m2) than the other fallow treatment plots ($\leq$ 2.25) (Figure 1-15). In addition, there were significant differences in browntop millet counts between herbicide and non herbicide plots. At the beginning and end of the second year of fallowing, both herbicides reduced browntop millet counts (0-1.25 browntop millet/m2) compared to non herbicide plots (6-11 browntop millet/m2)

(Figure 1-16). Glyphosate provided excellent post emergent control of browntop millet. The addition of halosulfuron was not expected to increase the pre emergent control of browntop millet.

Smallflower morningglory (data not shown)

There is no consistent pattern of control for smallflower morningglory over time using any of the fallow treatments tested, except for glyphosate with cultivation which gave fairly consistent morningglory control during the fallow period. There were no significant differences in smallflower morningglory counts due to any fallow treatments or factors implemented. Although the herbicides did not kill all the smallflower morningglory plants, they caused severe damage and prevented the plants from growing, flowering, and producing seeds normally. In this manner, glyphosate may lower the amount of smallflower morningglory present in the field over a long period of time.

This same trend was observed by Sharma and Singh (2007) when applying glyphosate to ivyleaf morningglory. They found that ivyleaf morningglory flowering was inhibited by an application of glyphosate at 2.5 kg/hg. In addition, glyphosate altered the plant architecture of ivyleaf morningglory, causing the loss of apical dominance and production of lateral branches. In their study, glyphosate reduced the biomass of ivyleaf morningglory by 14-24%. According to their study, glyphosate efficacy to kill ivy leaf morning glory was dependent on the age of the plant. Glyphosate applied at a rate of 1.25kg/ha to 3-week old plants provided 44% control of ivyleaf morningglory. As ivy leaf morningglory plant age increased, percent control decreased. This difference in ivyleaf morningglory control was significant between applications made to 3-week old plants and 7-week old plants.

Carpetweed fallow

There was an overall pattern where carpetweed numbers were greatest in the cultivation check plots and the glyphosate followed by cultivation plots (Figure 1-17). According to the analysis of variance there was an interaction in carpetweed counts between herbicides and cultivation.

Following the first herbicide application and tillage during the second fallowing season, all methods (0.5 to 2.75 carpetweed/m2) reduced carpetweed counts more than the cultivated check (13 carpetweed/m2) and glyphosate followed by cultivation (12 carpetweed/m2) (Figure 1-18). Cultivation increased carpetweed numbers. Although glyphosate killed the carpetweed that was present when it was applied it did not provide residual preferment control after the soil was tilled. However, the addition of halosulfuron provided residual preferment control of carpetweed, thus counts were lower even after tillage.

After the last fallow herbicide applications were made the untreated (2.75 carpetweed/m2) and all herbicides (0 to 3.25 carpetweed/m2) reduced carpetweed better than cultivation alone (17 carpetweed/m2). As mentioned earlier, glyphosate and glyphosate plus halosulfuron provided excellent control of carpetweed. In addition, cultivation increased carpetweed counts by causing an immense flush of seedling germination.

Redweed fallow (data not shown)

Redweed was a major weed in Live Oak. No differences were found in redweed counts between treatments. Although there was no statistical difference in redweed numbers, there were notable observations in the plant morphology between herbicide and non-herbicide treated plots. In the untreated plots, redweed was allowed to develop, flower, and produce seeds normally. The herbicides did not kill redweed, which would explain why there was no difference in weed counts. However, the herbicides caused stunting, shortened nodes and sprouting. Although the herbicides did not kill redweed, they prevented the treated plants from growing normally and producing seeds during the fallow period.

Other minor weeds (data not shown)

There were other minor weeds, which were sparsely distributed throughout the field during the fallow period. These weeds were not prevalent in every plot and oftentimes not even an individual could be found in every replication. However, bermudagrass (located primarily along the outside boarders), goosegrass, sicklepod, southern sandbur, crowfootgrass, and pink purslane counts were taken when observed. Due to the inconsistent distribution and lack of prevalence no results could be fairly derived for these weeds.

Crop Data

Purple nutsedge in peppers - year 1

Purple nutsedge that penetrated through the plastic mulch during the cropping season was highest in the cultivated check plots, followed by the untreated plots, and the plots treated with herbicides had the least amount of purple nutsedge (Figure 1-19). Therefore, purple nutsedge infestation distribution during the first year of cropping was consistent with the results found for the fallow period. Sedges are known for their ability to penetrate through plastic mulch (and other physical barriers) due to their sharp leaf tips that cut through the mulch. In addition, their underground tuber reserves provide a carbohydrate source that allows the sedge to germinate and continue to grow for a relatively long period of time without sunlight before becoming depleted, compared to most seeds (especially small seeded species). Purple nutsedge continued to proliferate throughout the growing season, especially in the cultivated check (increased from 15 to 54 nutsedge /30 LBF) and untreated plots (increased from 6 to 17 nutsedge/30 LBF). These findings were typically of what might be expected in a spring crop, since temperatures began to get warmer throughout the season. Besides temperature, irrigation and fertilizers were applied during the crop, which were also beneficial to the growth of purple nutsedge.

In addition, herbicides significantly influenced purple nutsedge counts in bell peppers during the first cropping season. Glyphosate (0.9 to 4 nutsedge/30 LBF) and glyphosate tank mixed with halosulfuron (0.8 to 2.9 nutsedge/LBF) treated plots contained less purple nutsedge than non-herbicide treated plots (10 to 35.6 nutsedge/30 LBF). These findings are also consistent with the results obtained for purple nutsedge during the fallow period.

Weeds in pepper rows - year 1

There were many weeds other than purple nutsedge present within the rows of pepper during the first year. Unlike purple nutsedge, these weeds did not puncture the plastic mulch themselves, but instead grew through the holes punched in the mulch for the pepper transplants. Most weeds, besides sedges, are not able to germinate and penetrate through the black plastic mulch because it physically restricts light penetration (required to stimulate seed germination in certain species) and as a mechanical barrier to prevent weed emergence. Many times weeds germinate underneath the mulch and die due to the lack of light. Carpetweed, coreopsis, large crabgrass, hairy indigo, pink purslane, cutleaf evening primrose, Florida pusley, redweed, and smallflower morningglory were observed growing through the planting holes.

There was not a significant interaction in weed counts for any species between cultivation and herbicides in bell peppers rows. However the main effect of herbicide was significant for pusley and crabgrass counts. In addition, the main effect of cultivation was significant on crabgrass counts.

Pusley counts were higher in plots that were not treated with herbicides (104.5 pusley/ 30LBF) compared to plots treated with either glyphosate or glyphosate plus halosulfuron, 37 and 35 pusley/30 LBF, respectfully (Figure 1-21). There was not a difference in pusley counts between the glyphosate and glyphosate tank mixed with halosulfuron plots. In addition to post emergent control of pusley, halosulfuron was supposed to provide additional pre emergence control of pusley, however the added halosulfuron did not increase control of pusley as expected.

Similarly to pusley, crabgrass counts were lower in plots treated with either glyphosate (1.4 crabgrass/30 LBF) or glyphosate tank mixed with halosulfuron (1.3 crabgrass/30 LBF) compared to the plots not treated with herbicides (4 crabgrass/30 LBF) (Figure 1-22). Crabgrass counts were also lower in cultivated plots (1.25 crabgrass/30 LBF) compared to uncultivated plots (3.25 crabgrass/30 LBF) (Figure 1-23).

Weeds in pepper row middle - year 1

There were various species of weeds present in the pepper row middles during year 1. These weed include carpetweed, large crabgrass, hairy indigo, cutleaf evening primrose, purple nutsedge, Florida pusley, redweed, smallflower morningglory, and yellow nutsedge. The density of these weeds were much higher in the row middles compared to the rows, because the row middles were not covered with plastic mulch.

There were only two weed species that had significantly lower counts due to the fallow treatments. There was not a significant interaction in pusley or crabgrass counts between herbicide and cultivation. However, both species' counts were significantly different between the main effects of herbicides. This is consistent with the pattern found for these species in the pepper rows.

Florida pusley and large crabgrass counts were lower in plots that were treated with herbicides during the fallow than the non-herbicide plots. The counts for Florida pusley within the plots not treated with herbicide were 462 pusley/m2 and the counts in the herbicide plots were between 164 and 181 pusley/m2 (Figure 1-24). Crabgrass counts in the row middles that were not sprayed during the fallow period were 24 crabgrass/m2 and the counts in the herbicide treated row middles were between 10 and 11 crabgrass/m2 (Figure 1-25). There was not a difference in Florida pusley or large crabgrass counts in plots that were treated with glyphosate or glyphosate plus halosulfuron. It was expected that halosulfuron would provide additional control of crabgrass and pusley, however this was not the case.

Pepper heights - year 1

Pepper heights were noticeably different between treatments from visual observations. Therefore, six pepper heights were measured per plot to determine stunting from herbicide carryover. There was not a significant interaction in pepper heights between cultivation and herbicides, however the main effect of herbicides was significant. The plants in plots not treated with herbicide (26 cm) were significantly taller than the pepper plants grown in plots treated with herbicides (21-22 cm) (Figure 1-26). There was not a difference in pepper plant heights in rows that were treated with either herbicide treatment during the fallow period.

This data suggests that the herbicides may not have caused stunting, especially since glyphosate is known to be relatively non-toxic to crop plants, especially if the pre-plant interval is adhered to. Rather, it may be possible that the pepper plants in the non-herbicide plots were 'leggy' in response to competing with the other weeds for sunlight. Hunt (1988) found that stressed plants from low light conditions usually partition resources toward shoot elongation. However, the exact discrepancy in pepper heights between herbicide treatments cannot be determined by this experiment.

Weeds in beans - year 1

Carpetweed, coreopsis, crabgrass, hairy indigo, cutleaf evening primrose, purple nutsedge, Florida pusley, redweed, smallflower morningglory, and yellow nutsedge were present in the beans during the first cropping season. There were not significant interactions in the % ground cover of all weed species between herbicide and cultivation, however the main effect of herbicide was significant in regards to % cover. The overall infestation of all weeds combined was significantly different between fallow herbicide treatment plots (Figure 1-27). The percent ground cover of all weeds was highest in the bean rows that were not treated with herbicides (90%) during the fallow period. Percent cover was not significantly different between glyphosate (53%) and glyphosate plus halosulfuron treated plots (55%). These results are reasonable, since a large portion of the weeds comprising the total weed cover were significantly different between herbicide treatments including purple nutsedge, pusley (primary species present in field), and crabgrass.

Analysis of variance indicated that there was not a significant interaction in purple nutsedge counts between herbicide and cultivation, however the herbicide main effect was significant. Unlike in the peppers, cultivation did not play an effect in purple nutsedge counts in the beans during the first cropping season. A possible explanation, is that there was competition from other weeds present in the beans. Since it is grown on bare ground without mulch, purple nutsedge was not allowed to proliferate in the same manner that was observed in the peppers on mulched beds with a drastically lower amount of competition from other weeds.

As stated, there was a significant difference in purple nutsedge counts in the bean rows between herbicide treatments during the first cropping season (Figure 1-28). Purple nutsedge densities were highest in the bean plots that were not treated with herbicides (29 nutsedge/m2) during the previous fallow period. There was no significant difference in purple nutsedge counts between the herbicide treatments (0-0.5 nutsedge/m2). Purple nutsedge was virtually eradicated in the bean plots that were treated with either herbicide treatment. As discussed earlier, there was a lot of interspecific competition with nutsedge in the beans during the first year. This was largely due to the ineffectiveness of the pre-plant herbicide applied prior to planting which would typically control most of the weeds present in the field, except for purple nutsedge and sexually propagated weeds with hard seed coats. It is theorized that s-metolachlor did not provide adequate control of several weed species because there was a lack of adequate soil moisture present at the time of application. S-metolachlor and most other pre plant herbicides require enough soil moisture to move the pre plant herbicide into the soil where it controls the imbibing and germinating seeds. If supplemental irrigation had been provided, greater control of certain weeds would have been expected. There was disfiguration and herbicide symptomology (more spindly plants with thinner, yellower leaves) observed in many of the weeds (especially Florida pusley), however the pre-plant application did not result in plant death as expected.

There was not a significant interaction in Florida pusley counts between herbicides and cultivation, but the main effect of herbicide was significant. Florida pusley densities were significantly higher in plots that were not treated with herbicides during the summer before planting (388 pusley/m2) (Figure 1-29). Pusley counts were not significantly different between plots treated with glyphosate or glyphosate tank mixed together with halosulfuron, 96 and 83 pusley/m2 respectfully. It was expected that cultivation and the addition of halosulfuron would provide superior control of pusley. The amount of pusley present in the field would have been reduced with a proper application of s-metolachlor under ideal environmental conditions.

This same pattern was recognized with crabgrass counts in the bean rows. There was not a significant interaction in crabgrass counts between herbicides and cultivation (at the alpha = .05 level), but the main effects of both herbicides and cultivation was significant. The plots that were not treated with herbicides had a significantly higher number of crabgrass (16 crabgrass/m2) than the herbicide plots and there was no difference between herbicide plots (3-6 crabgrass/m2)(Figure 1-30). However, numerically crabgrass numbers were lowest in the plots treated with both glyphosate and halosulfuron. In addition, crabgrass densities were significantly greater in plots that were not cultivated (13 crabgrass/m2) during the previous fallowing period, when compared to the cultivated plots 3 crabgrass/m2) (Figure 1-31). Although, the pre plant application was not effective at controlling weeds that are typically controlled by s-metolachlor, this highlighted the sole effect of the fallow treatments on weed control and made their effect more pronounced, which is important to understand, especially in minor vegetable crops which have no labeled pre-plant herbicides.

Crop yields - year 1 (data not shown)

There were not any significant interactions in pepper yields between herbicide and cultivation. In addition, the main effect of herbicide or cultivation on pepper yields were not significant. Unfortunately there were no significant differences in pepper yields for the first harvest, the second harvest or the total marketable fruit yield. In our experiment the use of cultivation, glyphosate, glyphosate tank-mixed with halosulfuron or combinations of these fallow techniques did not improve pepper yields significantly. However, there was great variability between replications which was mainly attributed to deer damage. Furthermore, we were not able to mechanically harvest the snap beans the first cropping season due to the heavy impenetrable weed densities present in the field. Green beans are typically harvested by machine in Florida, therefore if the beans could not be harvested mechanically it is not practical to harvest them by hand, since it will not be applied by farmers.

Purple nutsedge within the pepper row - year 2

There were three different pre-plant herbicides included in the second year experiment to determine which combination of fallow treatment and pre-plant herbicide treatment most effectively controlled specific weed species in peppers.

The results of the study were different in the second year compared to the first. During the second year, the untreated control consistently had the highest number of purple nutsedge over three sampling dates ($\geq$ 86 purple nutsedge/30 LBF), followed by the cultivated check ($\geq$ 39 purple nutsedge/30 LBF), and than the herbicide treatments ($\geq$13 purple nutsedge/m2) (Figure 1-32). When left untreated, purple nutsedge numbers increase initially and then decrease during the fall growing season. The increase and decline in nutsedge population can be explained by the weather conditions. During the summer, nutsedge increased due to the warm, wet growing conditions needed for nutsedge to grow and proliferate. But, during the fall, temperatures and rainfall decreased and purple nutsedge is known to decline in numbers and enter dormancy under these unfavorable growing conditions.

It appears that after two years of summer fallowing, cultivation began to control purple nutsedge compared to the untreated control. Therefore, tillage holds a possibility of providing nutsedge control if a long term approach is adopted. In addition, the first crop was planted in the spring and the long period of inactivity may have caused nutsedge in the tilled plots to establish, proliferate, and continue to propagate. During the second year, there was a quick succession of cultivation events and the entire field was cultivated prior to bed preparation and planting. Thus, purple nutsedge in the cultivated plots may not have had time to establish between tillage events and this caused tuber desiccation, carbohydrate depletion, and death. In addition, the cultivation before planting may have caused an increase in purple nutsedge counts in the untreated plots that was not apparent during the fallow season, because apical dormancy was released.

The effects of herbicides were significant for purple nutsedge counts during the second bell pepper crop. Herbicides lowered purple nutsedge dramatically ($\leq$ 10 purple nutsedge/30 LBF) compared to no herbicides ($\geq$ 62.5 purple nutsedge/30 LBF) (Figure 1-33). This was similar to the trends observed in purple nutsedge during the first growing season.

EPTC was expected to provide control of purple nutsedge since previous studies have revealed that EPTC applied under the plastic in tomatoes was shown to be effective at controlling purple nutsedge (McAvoy and Stall, 2008; Santos 2009), however the irrigation methods differed between these experiments and ours. In the first study seepage irrigation was used, thus water was being pushed up to the soil surface from below, this provided adequate soil moisture to the herbicide without causing it to leach through the soil surface. In the second study (which was being conducted simultaneously with our experiment), EPTC was applied either sprayed on the soil surface underneath the plastic or applied through drip irrigation. Santos (2009) found that excessive irrigation from drip applications caused EPTC to be washed down into the soil profile which caused it to be ineffective at controlling nutsedge sprouting (because most nutsedge tubers are near the soil surface) and caused toxicity to tomato plants when they grew bigger and their roots penetrated the contaminated zone in the soil. Therefore, it can be concluded that EPTC may have been effective at controlling purple nutsedge if the proper amount of drip irrigation was provided. Basically enough irrigation to keep the soil moist without causing leaching of the chemicals.

There were weeds that began to emerge through the planting holes during the second pepper crop, however an early frost prevented the identification and data collection of these weeds.

Cabbage weeds - year 2

There were many weeds present in the cabbage crop that was grown during the second year of the study. In addition to many of the weeds present during the spring crop, there were also several winter annuals in the fall/winter crop that were not observed during the first crop or the summer fallow period. The weed population consisted of purple nutsedge, pusley, crabgrass, smallflower morningglory, cutleaf evening primrose, wild mustard, and coreopsis. However, wild mustard and coreopsis were not prevalent in all areas of the field.

There was a significant interaction in purple nutsedge counts between fallow herbicides and cultivation techniques. Purple nutsedge control in the cabbage crop was lowest in the untreated fallow plots, moderate in the cultivated check plots (53% control) and highest in the remaining plots ($\geq$94% control) (Figure 1-34). The level of purple nutsedge control provided by the various fallow treatments in cabbage was similar to the level of purple nutsedge control found in the peppers.

There were no interactions in smallflower morningglory percent control ratings between herbicide, cultivation and pre plant herbicides or any combinations of the three. However, the main effect of pre plant herbicides was significant. There was a significant difference in the smallflower morningglory control between pre-plant herbicide treatments within the cabbage rows. The rows treated with oxyfluorfen resulted in the highest level of smallflower morningglory control (95% control) (Figure 1-35). S-metolachlor controlled smallflower morningglory better (76% control) than the untreated control but significantly less than oxyfluorfen (95% control).

Florida pusley and large crabgrass control ratings in the cabbage crop did not have significant interactions between fallow herbicides, fallow cultivation and pre plant herbicides. However, there were significant interactions in both weed control ratings between cultivation and pre plant herbicide. Therefore, significant Florida pusley and crabgrass control was obtained within the cabbage crop. Control of Florida pusley and crabgrass was dependent on the combined effect of fallow cultivation and pre plant herbicide application when transplanting.

Oxyfluorfen applied to either cultivated or uncultivated fallow plots provided the best control of Florida pusley (above 95% control) (Figure 1-36). S-metolachlor provided better Florida pusley control in plots that were cultivated during the fallow period (61% control) compared to plots that were not cultivated (40 % control). S-metolachlor did not control (40 to 61 % control) Florida pusley as well as oxyfluorfen (95 to 98% control). Plots that were not treated with a pre plant herbicide had the poorest Florida pusley control, regardless of cultivation practice during the fallow period. Thus the main factor that contributed to pusley control in the cabbage crop was the pre plant herbicide in which oxyfluorfen controlled pusley better than s-metolachlor. Since pusley infestation occurs from seeds within the soil it would make sense that a pre plant herbicide to kill germinating seeds would be necessary to prevent establishment in a cropping situation. However, cultivation controlled pusley better than no cultivation. These results can be explained by the fact that although cultivation and herbicides both controlled pusley in the fallow period, and thus subsequently prevented the weeds from flowering and setting seeds. In addition to preventing seed rain it was apparent that tillage may have in some cases reduced the number of viable seeds in the soil seed bank by stimulating germination and by seed burial. Lastly, fallow cultivation may have broken up the crop residues and clumps in the soil thus providing a fluffy soil with good tilth that would provide a greater surface contact for the pre plant herbicides when applying and greater pre plant herbicide movement within the soil.

The control of crabgrass was highest in the plots that were treated with oxyfluorfen whether cultivation was performed during the summer or not (99% control) and in plots that were cultivated during the summer than treated with s-metolachlor after planting (94% control) (Figure 1-37). S-metolachlor did not control crabgrass as well when cultivation was not implemented during the fallow period (83% control). Plots that were not treated with a pre plant herbicide resulted in the lowest control of crabgrass even if the plot was cultivated during the fallow period. Crabgrass and pusley had a similar response to the effect of cultivation and pre plant herbicides. The same factors that affected the pusley control level would likely explain the control realized in large crabgrass. These weeds may have responded similarly due to similarities between the two species. Both plants reproduce primarily by seed, both are summer annuals, and both produce a small seed that does not remain dormant in the soil for long periods of time.

There was no interaction in cutleaf eveningprimrose control between fallow herbicide, fallow cultivation, and pre plant herbicide. However, there was a significant interaction in cutleaf evening primrose control between fallow herbicides and pre plant herbicides. The control of cutleaf evening primrose was significantly different in the plots between the combinations of fallow herbicides and pre plant herbicides. Cutleaf evening primrose was controlled best in all the plots that were treated with oxyfluorfen prior to transplanting no matter what fallow herbicide was applied ($\geq$ 94% control)(Figure 1-38). The application of s-metolachlor did not control cutleaf evening primrose (26 to 54 % control) as well as oxyfluorfen applications. S-metolachlor provided better control of cutleaf evening primrose in plots that were not treated with herbicide during the fallow period (54% control) and in plots that were treated with glyphosate tank mixed with halosulfuron (49% control). The application of s-metolachlor in plots that were treated with glyphosate when fallowing resulted in decreased cutleaf evening primrose control (26% control). The control of cutleaf evening primrose was poorest in plots that were not treated with a pre plant herbicide, despite the fallow herbicide treatment that was used. In summary, oxyfluorfen controlled cutleaf evening primrose better than s-metolachlor, and s-metolachlor controlled cutleaf eveningprimrose better than no pre plant herbicide. It is uncertain why glyphosate applied during the fallow hindered the effect of a pre-plant application of s-metolachlor on cutleaf eveningprimrose control during the growing season. However, the level of reduction was significant. The experiment should be replicated to verify the reproducibility of these results.

Bean weeds - year 2

The weeds within the beans included: purple nutsedge, pusley, crabgrass, smallflower morningglory, cutleaf evening primrose, wild mustard, and coreopsis. However, wild mustard and coreopsis were not uniformly distributed within the experimental area. As explained earlier, several of these winter annuals such as cutleaf evening primrose, wild mustard and coreopsis were not present during the summer fallow period and were not as prevalent during the spring crop. Therefore, it would be assumed that summer fallow techniques would not control winter annuals.

There were not any significant interactions in weed control between fallow herbicide, fallow cultivation and pre plant herbicides for any of the weeds in the field. However, there was an interaction in pusley control between fallow herbicide and pre plant herbicide, and fallow cultivation and pre plant herbicide. In addition, the main effect of pre plant herbicides were significant for the control of large crabgrass, cutleaf eveningprimrose, and smallflower morningglory. The main effect of fallow herbicides was significant for controlling smallflower morningglory and purple nutsedge.

There were significant differences in the control of crabgrass, cutleaf eveningprimrose and smallflower morningglory between pre plant herbicides. S-metolachlor and pendimethalin provided the best control ($\geq$ 98% control) of crabgrass in beans (Figure 1-39). EPTC gave good control of crabgrass (90% control) and no pre plant herbicide resulted in the poorest crabgrass control.

The application of s-metolachlor provided the highest level of cutleaf evening primrose control (89%) (Figure 1-40). EPTC controlled cutleaf eveningprimrose (56% control) better than pendimethalin (34% control) and the untreated check.

All pre plant herbicides provided better control of smallflower morningglory ($\geq$ 83% control) than the untreated check (Figure 1-41). These results indicate that although fallow cultivation and herbicides may control these weeds during the summer, a pre plant herbicide should still be used to prevent weed infestation during the crop. There are a large amount of viable seeds within the soil seedbank that remain dormant until there are favorable conditions for them to grow. This is especially true for rudimentary species in disturbed soil surfaces such as those encountered in conventional cropping systems.

There was also a significant difference in the level of smallflower morningglory control between fallow herbicides. Glyphosate plus halosulfuron applications resulted in better control of smallflower morningglory (75% control) than the untreated check (55% control) but provided similar levels of control as glyphosate by itself (67% control) (Figure 1-42). Fallow applications of glyphosate provided similar levels of control (67% control) as the untreated herbicide check (55% control) and glyphosate tank mixed with halosulfuron (75% control). A possible explanation is that is that the halosulfuron provided additional pre emergent control of smallflower morningglory during the fallow period and therefore reduced the population during the crop.

Significant differences in pusley control were found between fallow herbicide/pre plant herbicide combinations and between fallow cultivation/pre plant herbicide combinations. In regards to the fallow herbicide/pre plant herbicide control of pusley, fallow without herbicide followed by s-metolachlor (97% control), no herbicide followed by pendimethalin (99% control), glyphosate followed by s-metolachlor (98% control), glyphosate followed by pendimethalin (99.6% control), glyphosate tank mixed with halosulfuron followed by EPTC (96% control), glyphosate tank mixed with halosulfuron followed by s-metolachlor (99% control) and glyphosate tank mixed with halosulfuron followed by pendimethalin (100% control) gave the best control (Figure 1-43). Glyphosate followed by EPTC (93% control) did not control Florida pusley as well as glyphosate followed by pendimethalin (99.6% control) and halosulfuron tank mixed with glyphosate followed by pendimethalin (100% control). All plots where a pre plant herbicide was not applied had the most severe pusley infestation. It appears that EPTC did not control pusley as well as the other herbicides especially when there were no herbicides applied during the fallow. Overall all pre plant herbicides controlled pusley better than the untreated pre plant scenario. These results indicate that s-metolachlor or pendimethalin (numerically better control) should be used to control pusley in beans. However, if EPTC is used as a pre plant than it would be advantageous to used with fallow herbicides, specifically glyphosate tank mixed with halosulfuron during the fallow season.

In regards to the fallow cultivation/pre plant herbicide control of pusley, s-metolachlor and pendimethalin with or without cultivation resulted in the highest level of pusley control ($\geq$ 98% control) (Figure 1-44). EPTC in combination with fallow cultivation gave better control of pusley (93% control) than without fallow cultivation (84% control). All plots that were not treated with pre plant herbicides had the most pusley regardless of fallow cultivation technique. Therefore, it would be recommended that s-metolachlor be applied pre plant in beans to control pusley. However, if EPTC was being used it would be better to cultivate rather than not cultivate. These results suggest that excellent pusley control can be obtained with the proper pre plant herbicides, however if suboptimal pre plant herbicides were used it would be beneficial to apply fallow herbicides or till during the fallow period to achieve better pusley control.

There was a significant difference in purple nutsedge control between fallow herbicide treatments in the bean crop of the second year. Both glyphosate and glyphosate tank-mixed with halosulfuron ($\geq$ 95% control) provided better control of purple nutsedge than the untreated herbicide areas (6% control) (Figure 1-45). These results are consistent with the findings we found for purple nutsedge in the fallow period, in the first bean crop, and in the peppers. This shows that systemic post emergent herbicides (glyphosate and glyphosate plus halosulfuron) greatly increased the level of purple nutsedge control compared to not utilizing herbicides during the fallow period. The explanation for these findings were stated earlier in the fallow section.

Pepper and bean dry weights - year 2 (data not shown)

There were no significant interactions in pepper or bean plant dry weights between fallow cultivation, fallow herbicides, and pre plant herbicides or any combination of these factors. In addition the main effects of fallow cultivation, fallow herbicides, or pre plant herbicides did not significantly affect pepper or green bean plant dry weights. There were no significant differences in bell pepper or green bean plant dry weights between fallow tillage, fallow herbicide and pre plant herbicide treatments or the various combinations of the three (data not shown). No fruit yield was obtained from either crop due to an untimely frost event. The peppers were at first flower growth stage and the beans had begun to flower when they were frozen to the ground. In addition, the weeds were very small when the frost occurred. Since the crops were at a uniform growth stage and the weeds were very small during the frost event there were not any significant differences in weights because the weeds did not compete long enough with the crop to hinder growth, and development. One would speculate that if the weeds were allowed to compete with the crop all season long there may have been differences in crop yields since there were differences in weed control between the various fallow and pre-plant treatments.

Cabbage yield - year 2

There were not any significant interactions in cabbage numbers, cabbage weight, or average cabbage head weight between fallow herbicide, fallow tillage, and pre plant herbicides or any combination of these factors. However, pre plant herbicides main effects significantly impacted cabbage yields. There were significant differences in the number of cabbage per plot, the total cabbage yield per plot, and the average cabbage weight between the plots treated with pre-plant herbicides. The plots treated with oxyfluorfen produced the highest number of cabbage per plot (13 cabbage/15 LBF) (Figure 1-46). There were less cabbage plants in the plots that were not treated with a pre plant herbicide (11.5 cabbage/15 LBF). There was no difference in the number of cabbage in the plots treated with s-metolachlor (12.7 cabbage/15 LBF) when compared to the untreated (11.5 cabbage/15 LBF) or the oxyfluorfen treated plots (13 cabbage/15 LBF).

The total cabbage yield was highest in the plots treated with oxyfluorfen pre transplant (40 lbs/15 LBF) (Figure 1-47). S-metolachlor treated plots had yields (32 lbs/15 LBF) higher than the untreated plots (28 lbs/15 LBF) but not as high as the oxyfluorfen treated areas (40 lbs/15 LBF). The plots that were not treated with a pre plant herbicide had the lowest cabbage yield (28 lbs/30 LBF).

The average weight per cabbage was highest in the plots treated with oxyfluorfen (3.1 lbs) (Figure 1-48). The rows treated with s-metolachlor and the row not treated with a pre plant herbicide had similar sized cabbages on average (between 2.4 to 2.6 lbs). Although there were several weeds present at the beginning of the cabbage crop, most of the weeds died during the frost. As a result of the frost, the primary weed present during most of the cabbage growing season was cutleaf eveningprimrose. In addition, cabbage has been proven to be a strong competitor with other winter annuals, such as wild mustard during the winter season. Thus the effect of fallow cultivation and herbicides did not have an effect on cabbage yield. However, cabbage yield was strongly correlated to pre plant herbicides which significantly controlled cutleaf eveningprimrose.

Conclusions

Purple Nutsedge Control

Glyphosate by itself or tank mixed with halosulfuron was the most effective fallow method for controlling purple nutsedge regardless of tillage regiment. Cultivation increased the amount of purple nutsedge during the fallow period and during the first crop compared to the untreated check. However, after two years of cultivating during the fallow there was less purple nutsedge in the cultivated check plot than in the untreated check plot in the second crop. Thus, cultivation may be effective at controlling purple nutsedge if implemented over a long time period. In addition, none of the pre plant herbicides were effective at controlling purple nutsedge in peppers, cabbage, or snap beans. Therefore, fallow applications of glyphosate or glyphosate plus halosulfuron are crucial in controlling purple nutsedge within a crop, since methyl bromide fumigation prior to planting is no longer an option, and the pre plant herbicides tested were not effective at controlling purple nutsedge.

Yellow Nutsedge Control

Yellow nutsedge was controlled by all of the fallow treatments compared to the untreated check. Therefore, fallow cultivation and/or tillage provides adequate yellow nutsedge control. In addition, yellow nutsedge was practically non-existent except in the untreated control plots during the cropping period for both years. The pre plant herbicides were expected to control yellow nutsedge, however there were no significant differences since the infestation was so low during the cropping season.

Florida Pusley Control

Florida pusley was controlled by glyphosate and glyphosate plus halosulfuron, compared to the untreated control during the fallow period. At first, cultivation increased the amount of pusley but by the second year cultivation resulted in less pusley compared to not cultivating. To summarize the results of fallow control of Florida pusley, cultivation controlled pusley better than the untreated check and the treatments with herbicides controlled pusley better than the cultivated check. During the first spring crop pusley was controlled better by glyphosate and glyphosate plus halosulfuron than the non herbicide treatments in pepper beds, pepper row middles and in green bean rows. In the second cropping season fallow cultivation plus pre plant herbicides were significant at controlling pusley. Oxyfluorfen controlled pusley better than s-metolachlor or no pre plant herbicide with or without cultivation. S-metolachlor controlled pusley better with cultivation than without cultivation. In the second crop of snap beans both fallow herbicide plus pre plant herbicide and fallow cultivation plus pre plant herbicide were significant at controlling Florida pusley. Pendimethalin and s-metolachlor controlled Florida pusley the best. The efficacy of EPTC was dependent on fallow herbicide applications. When no fallow herbicides were applied, EPTC did not control pusley as good as pendimethalin and s-metolachlor, when glyphosate was applied during the fallow period EPTC provided the same level of pusley control as s-metolachlor but not pendimethalin, and when glyphosate plus halosulfuron was applied during the fallow period all the pre plant herbicides provided the same level of pusley control. Similarly, pendimethalin and s-metolachlor provided the best pusley control regardless of fallow cultivation technique, however EPTC provided better pusley control when the plots were tilled during the fallow period.

Large Crabgrass Control

Crabgrass control between fallow treatments varied by date. However, it appears that many times, any fallow treatment controlled large crabgrass better than the untreated check. Sometimes herbicides provided greater control of crabgrass than the cultivated check and sometimes they did not. In one case (after the first fallow applications were applied) glyphosate plus halosulfuron provided greater control of crabgrass than the cultivated check and glyphosate plus halosulfuron with cultivation. During the first crop, fallow applications of both glyphosate and glyphosate plus halosulfuron controlled crabgrass better than non-herbicide treatments in pepper row middles. In the first bean crop, both fallow cultivation and fallow herbicide applications were important in controlling crabgrass. Glyphosate and glyphosate plus halosulfuron controlled crabgrass better than the non-herbicide treatments. In addition, fallow cultivation controlled crabgrass better than the non-cultivated plots. During the second year, oxyfluorfen provided excellent control of crabgrass in cabbage independently of fallow cultivation. But, s-metolachlor controlled crabgrass better with fallow cultivation compared to no fallow cultivation. In the second bean crop, crabgrass control was dependent on pre plant herbicides. S-metolachlor and pendimethalin controlled crabgrass better than EPTC and the untreated check.

Hairy Indigo Control

Glyphosate and glyphosate plus halosulfuron controlled hairy indigo better than the non-herbicide treatments during the fallow period. However, hairy indigo control did not differ significantly during the cropping season at the 0.05 alpha level, but during the first bean crop hairy indigo counts were significantly different between treatments at the 0.1 alpha level. During the second crop hairy indigo was not present in the field, this is probably due to unfavorable growing conditions (cool and dry), found in the late fall when we planted.

Browntop Millet Control

Browntop millet was controlled in all the fallow treatments compared to the cultivated check during the fallow period. Therefore, cultivating alone increased the amount of browntop millet. In addition, glyphosate and glyphosate tank mixed with halosulfuron consistently controlled browntop millet better than the treatments that did not use herbicides in the fallow period (although the difference was not always significant). Browntop millet was not a problem during the cropping season, however it is possible that browntop millet was misidentified as crabgrass when it was small.

Smallflower Morningglory Control

Glyphosate treatments controlled smallflower morningglory better than non-herbicide treatments during the fallow period. However, glyphosate plus halosulfuron controlled smallflower morningglory better than the non-herbicide fallow treatments during the second green bean crop. In cabbage, the pre plant herbicide oxyfluorfen controlled smallflower morningglory better than s-metolachlor. In addition, all the pre plant herbicides provided better control of small flower morningglory than the untreated pre plant check in the second snap bean crop.

Carpetweed Control

At the end of two years of fallowing, all of the treatments controlled carpetweed better than the cultivated check. Therefore, tillage caused an increase in the carpetweed population. However, even after cultivation, halosulfuron provided preferment control of carpetweed during the fallow period.

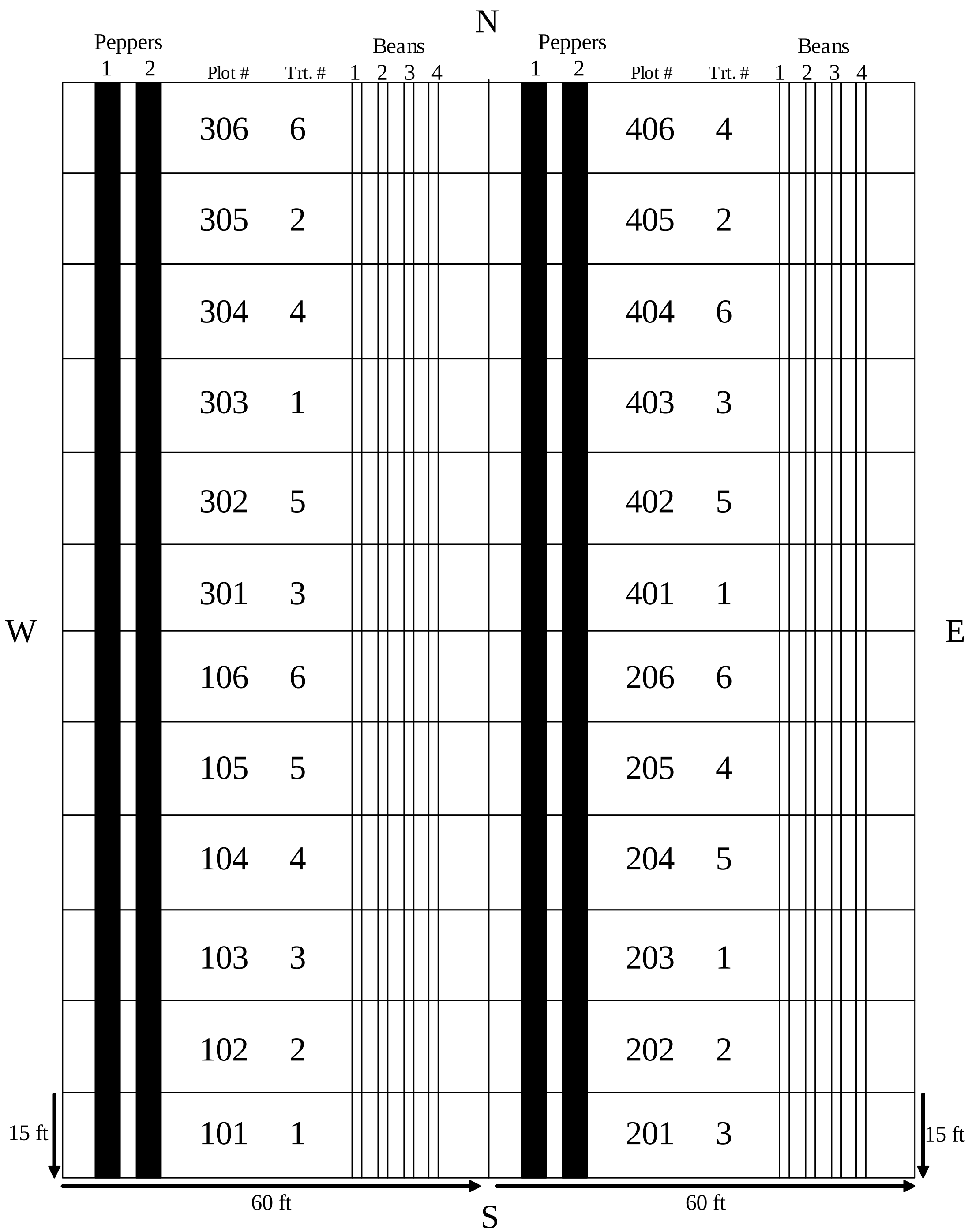
Cutleaf Evening Primrose Control

Cutleaf eveningprimrose was not represented during the fallow period. However, fallow herbicides along with pre plant herbicides affected cutleaf evening primrose control in cabbage.

Oxyfluorfen controlled cutleaf eveningprimrose better than s-metolachlor regardless of fallow herbicide used. In the second snap bean crop cutleaf evening primrose was controlled best by pre plant applications of s-metolachlor, than EPTC, than pendimethalin, which all controlled cutleaf evening primrose better than untreated pre plant check. Therefore, pre plant herbicides are necessary to control cutleaf eveningprimrose since it is not present during the fallow period.

Cabbage Yield

Cabbage total yield was dictated by which pre plant herbicide was used. Applications of oxyfluorfen resulted in the highest cabbage number per plot, average cabbage weight, and cabbage total weight. S-metolachlor resulted in similar cabbage numbers, but did not perform as well at controlling weeds (especially cutleaf evening primrose) as oxyfluorfen, therefore the average cabbage head weight and the total cabbage weight per plot was lower in s-metolachlor treated plots compared to oxyfluorfen treated plots. However, s-metolachlor improved cabbage yields compared to the untreated pre plant herbicide check. In conclusions, neither oxyfluorfen nor s-metolachlor hurt cabbage growth but oxyfluorfen controlled most of the weeds present in the field better.



Plot #:	Replication
101- 106	1
201- 206	2
301- 306	3
401- 406	4

Treatment #:	Treatment Received
1	Disk, Untreated
2	Disk, Glyphosate, NIS
3	Disk, Glyphosate + Halosulfuron-methyl, NIS
4	No Disk, Untreated
5	No Disk, Glyphosate, NIS
6	No Disk, Glyphosate + Halosulfuron-methyl, NIS

Figure 1-1. Experimental design of Live Oak, FL experiment during the first year.

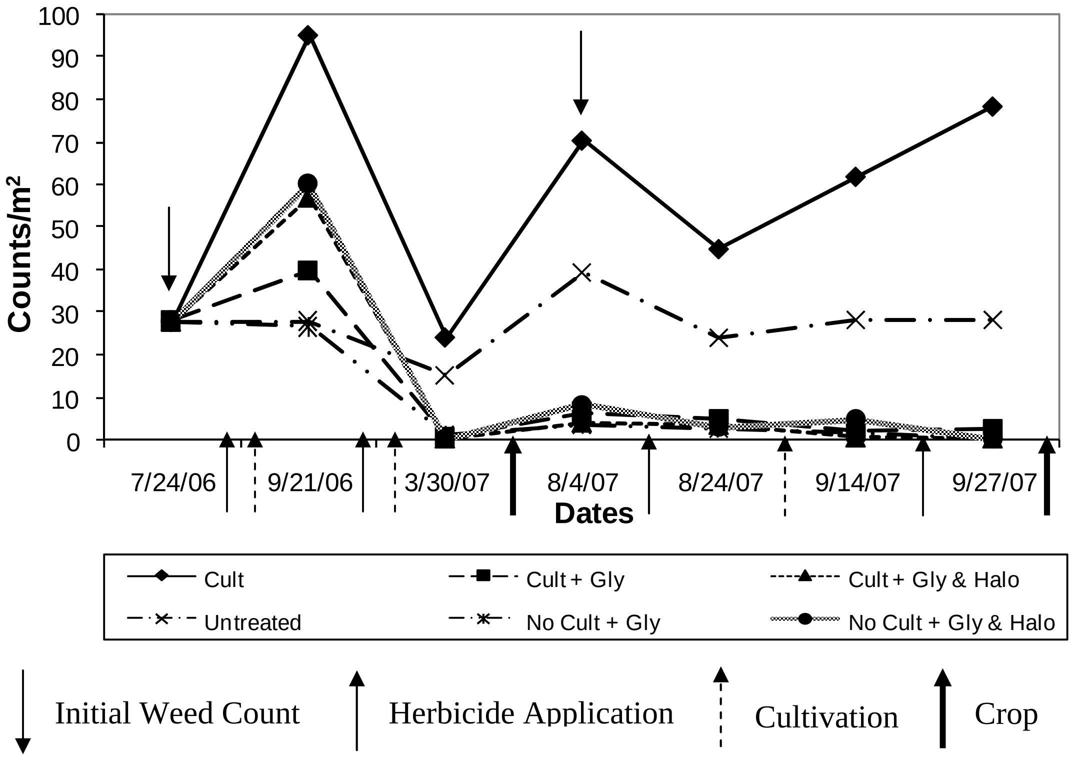


Figure 1-2. Purple nutsedge counts during the summer 2006 and 2007 fallow period in Live Oak, Fl. Weed counts include all living plants independent of visual health. Note x axis dates and treatment applications timelines are not drawn to scale.

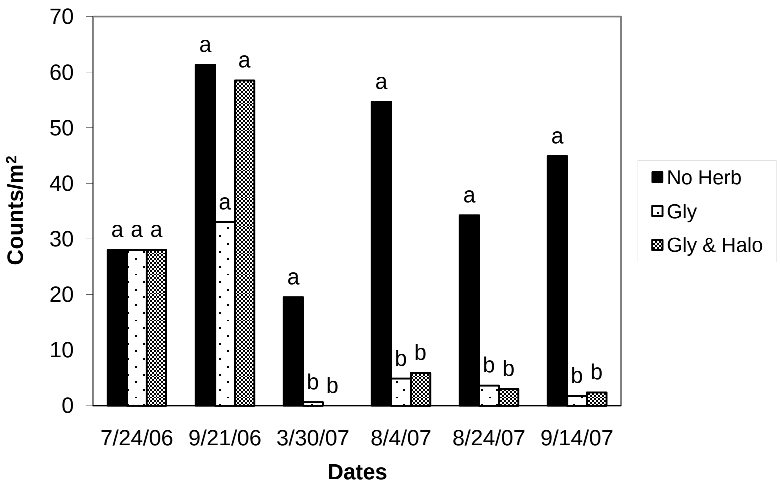


Figure 1-3. Effect of herbicides on purple nutsedge counts during the summer 2006 and 2007 fallow period in Live Oak, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Note x axis dates are not drawn to scale.

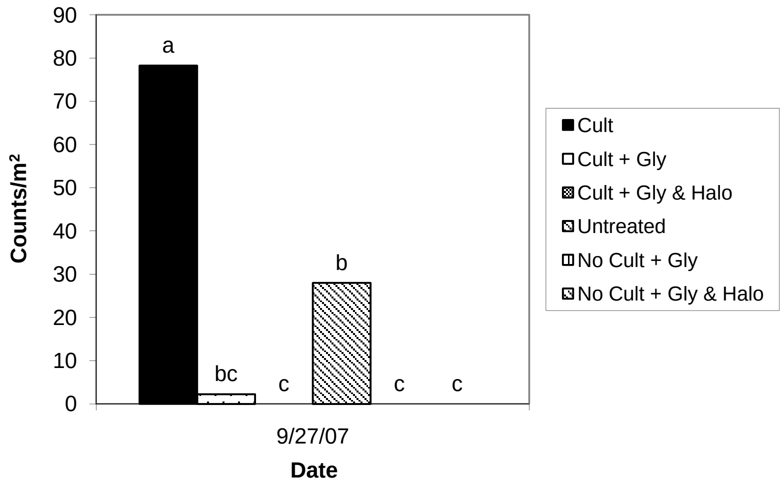


Figure 1-4. Effect of treatments on purple nutsedge counts during the summer 2007 fallow period in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health.

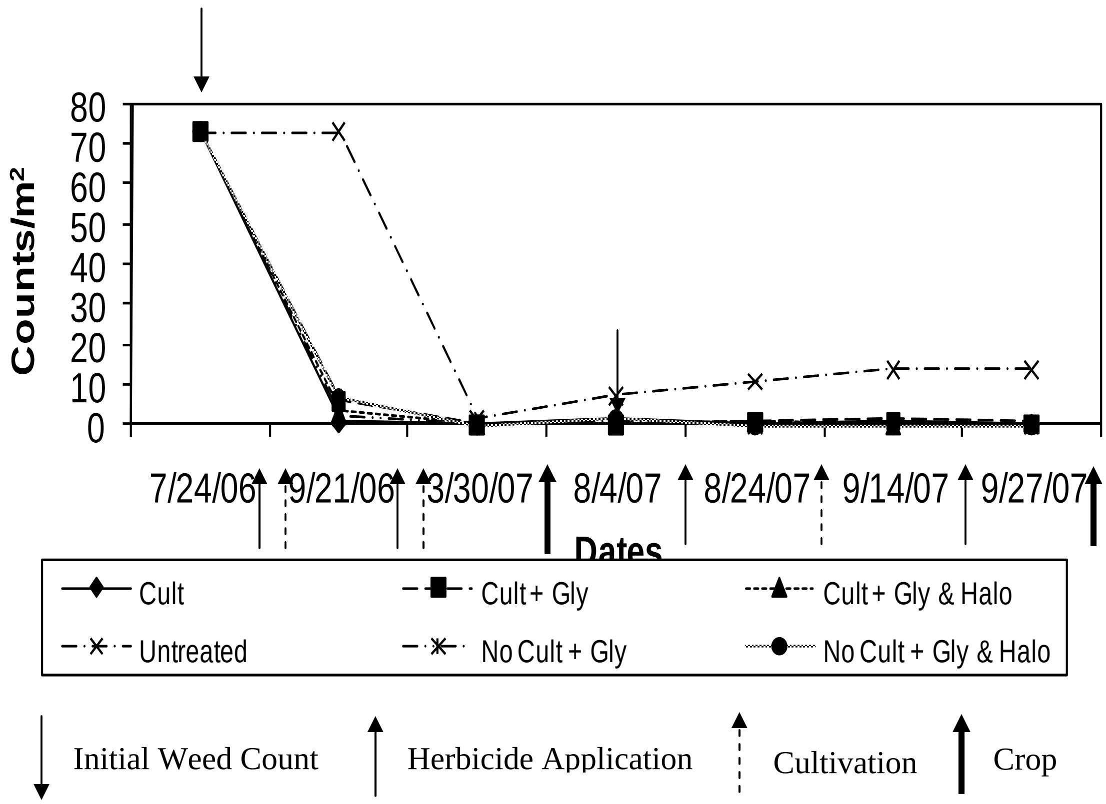


Figure 1-5. Yellow nutsedge counts during the summer 2006 and 2007 fallow period in Live Oak, Fl. Weed counts include all living plants independent of visual health. Note x axis dates and treatment applications timelines are not drawn to scale.

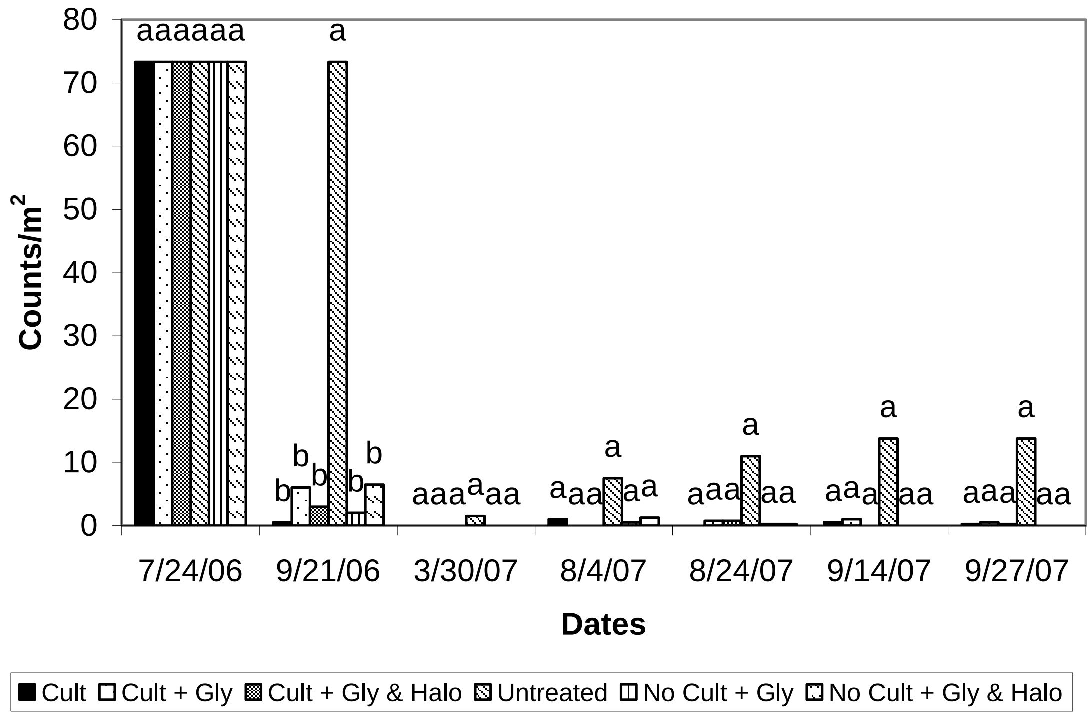


Figure 1-6. Effect of treatment by date interaction on yellow nutsedge counts during the summer 2006 and 2007 fallow period in Live Oak, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Note x axis dates are not drawn to scale.

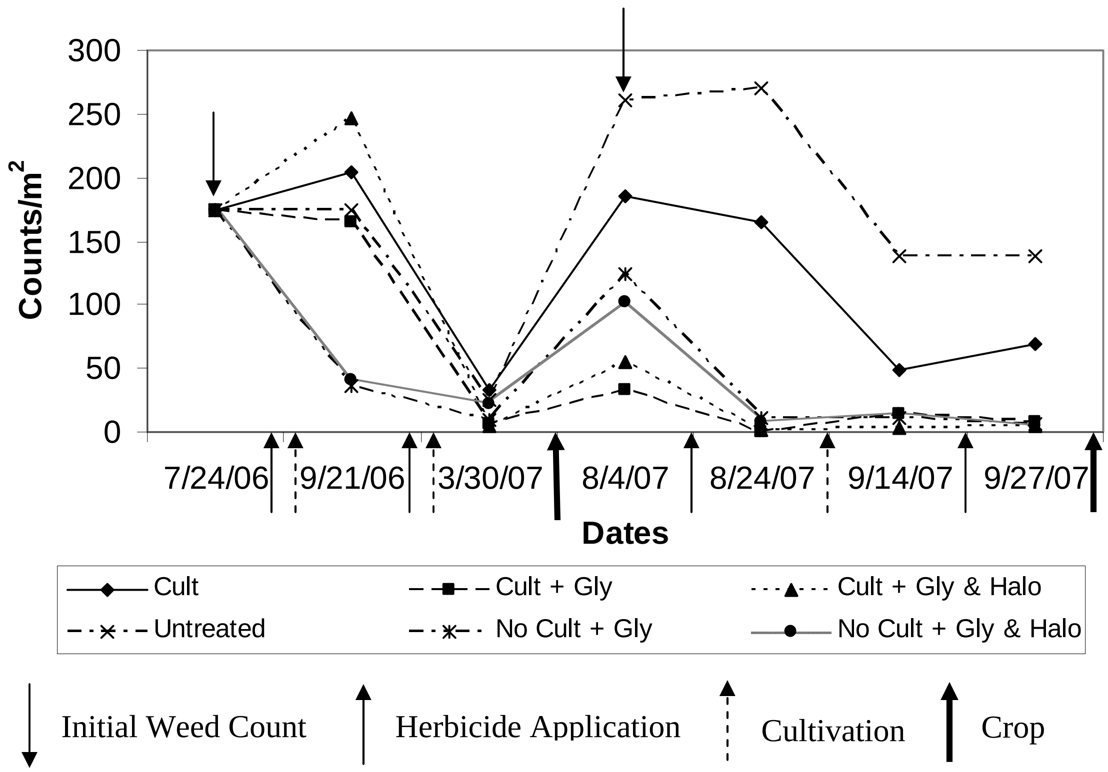


Figure 1-7. Florida pusley counts during the summer 2006 and 2007 fallow period in Live Oak, Fl. Weed counts include all living plants independent of visual health. Note x axis dates and treatment applications timelines are not drawn to scale.

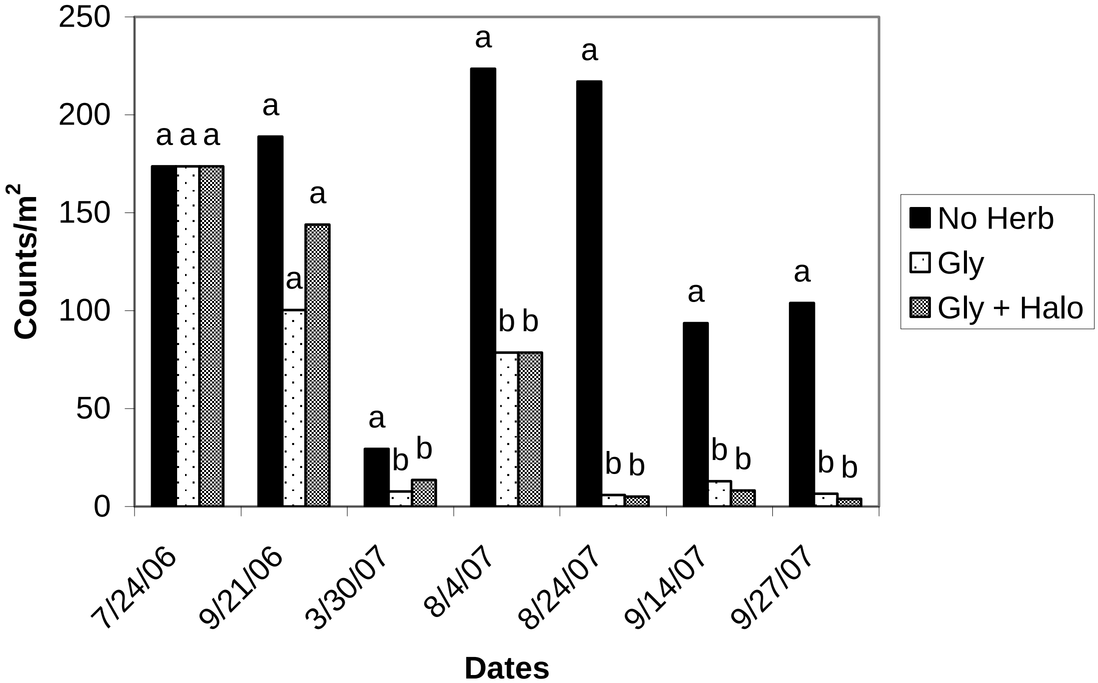


Figure 1-8. Effect of herbicides on Florida pusley counts during the summer 2006 and 2007 fallow period. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Note x axis dates are not drawn to scale.

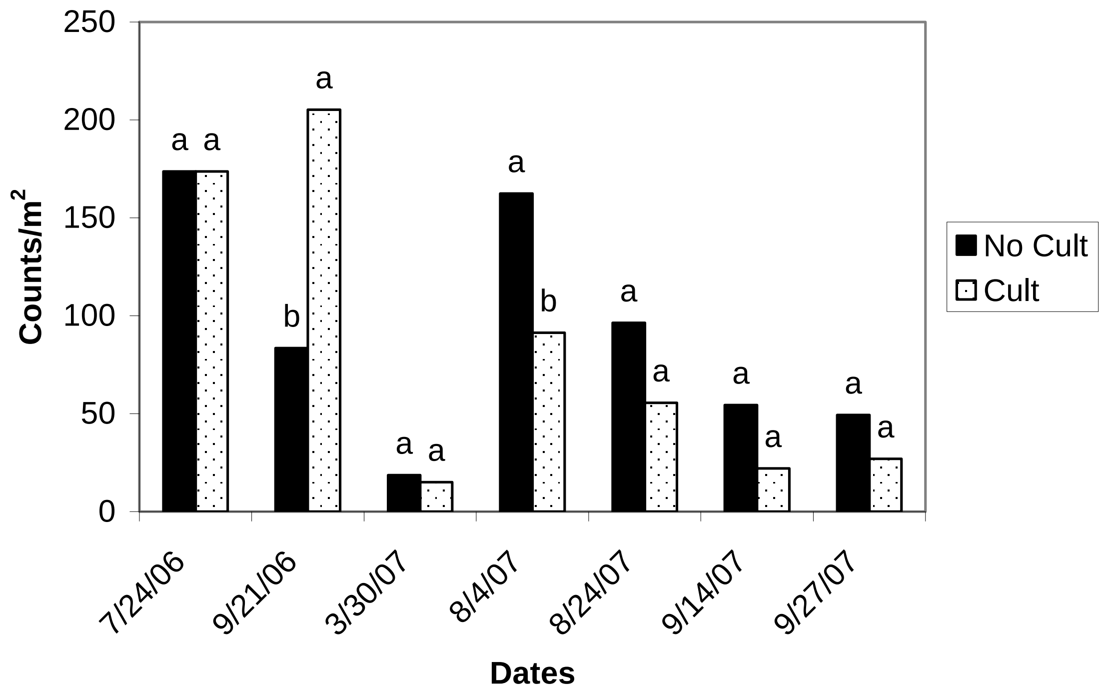


Figure 1-9. Effect of cultivation on Florida pusley counts during the summer 2006 and 2007 fallow period. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Note x axis dates are not drawn to scale.

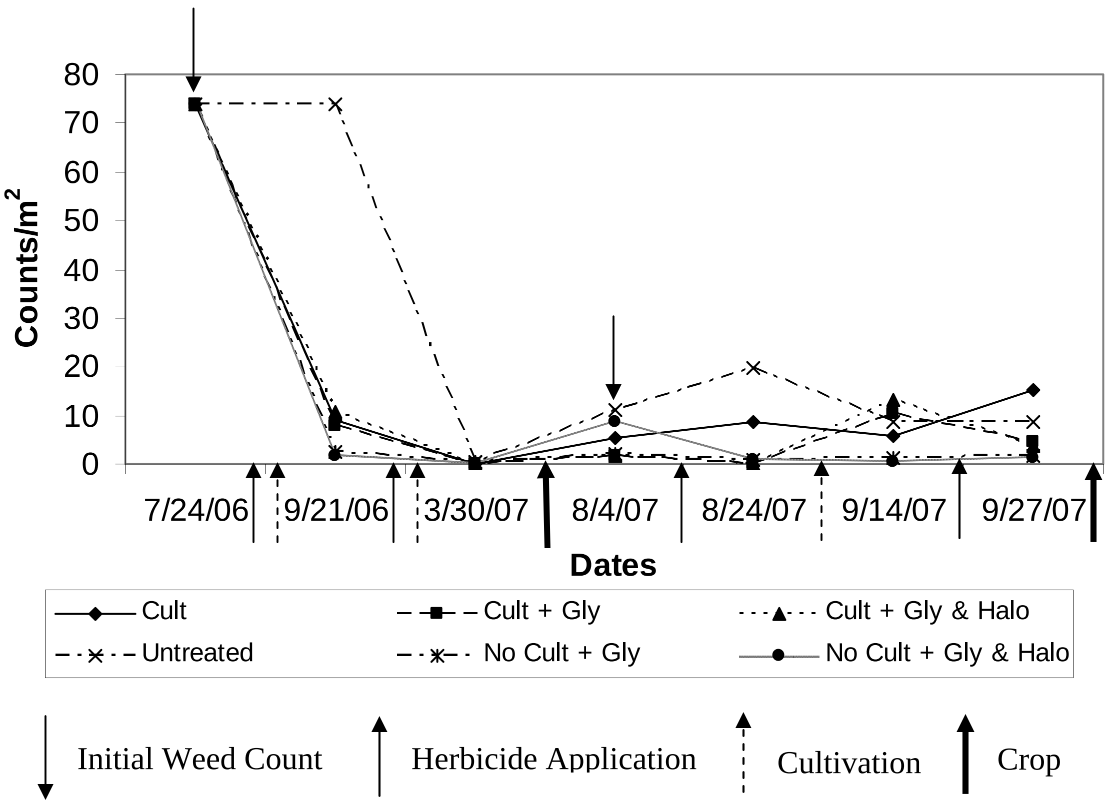


Figure 1-10. Large crabgrass counts during the summer 2006 and 2007 fallow period in Live Oak, Fl. Weed counts include all living plants independent of visual health. Note x axis dates and treatment applications timelines are not drawn to scale.

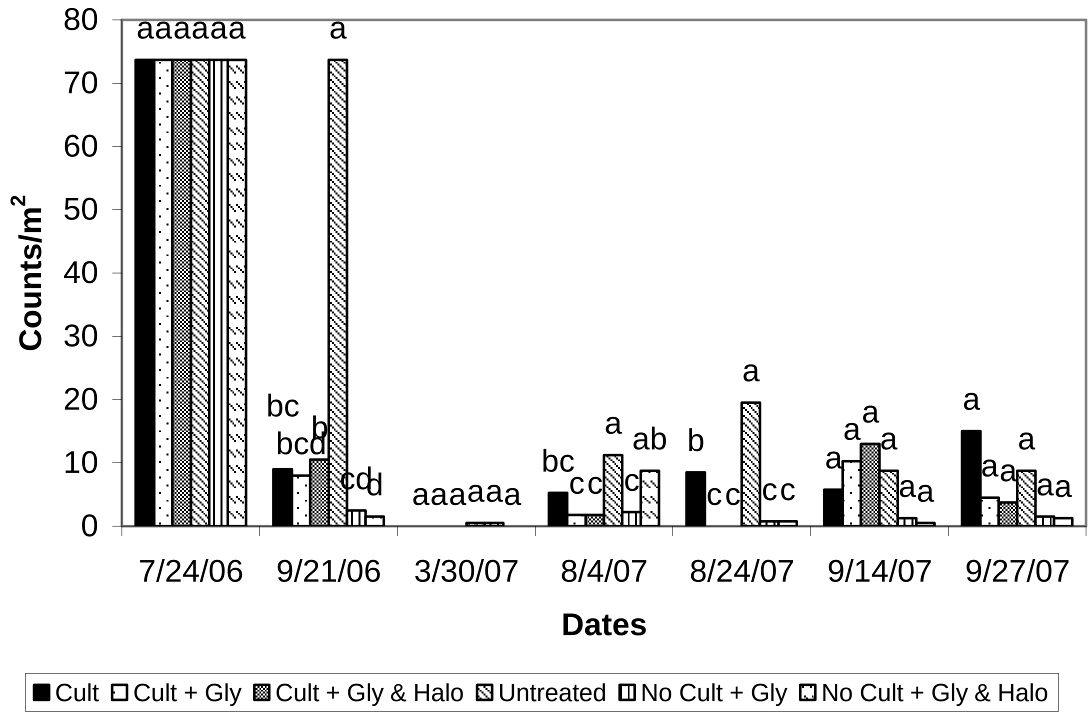


Figure 1-11. Interaction effect of treatment and date on large crabgrass counts during the summer 2006 and 2007 fallow period in Live Oak, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Note x axis dates are not drawn to scale.

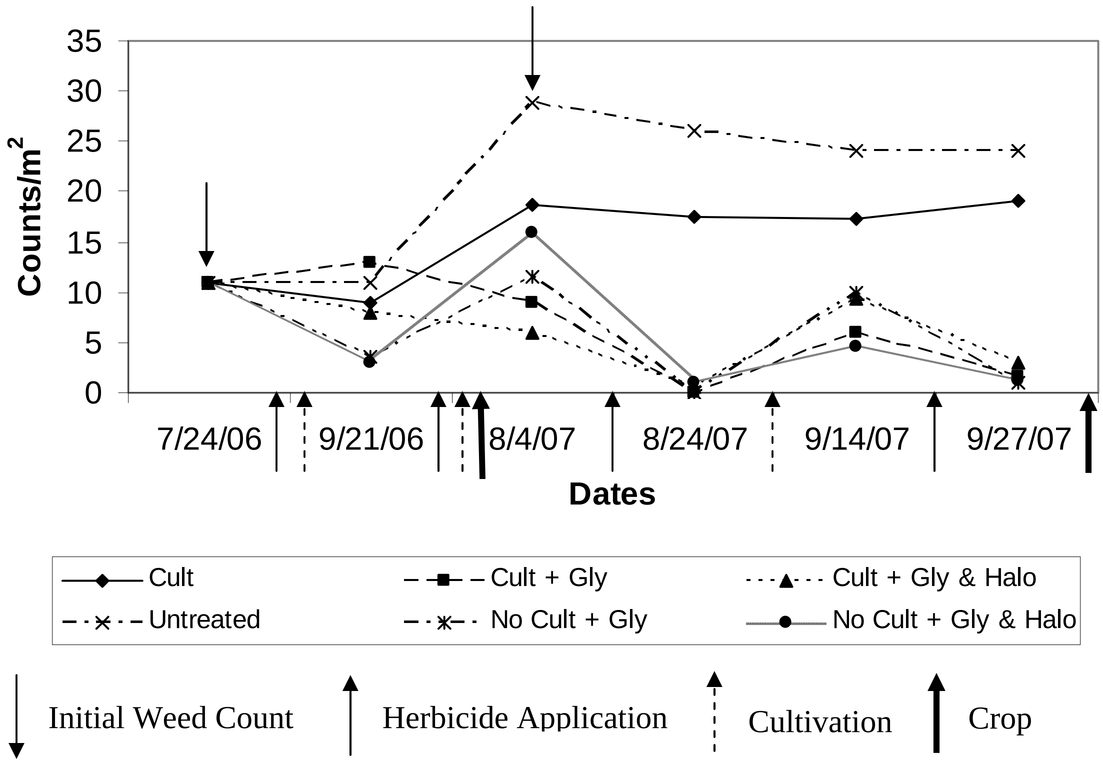


Figure 1-12. Hairy Indigo counts during the summer 2006 and 2007 fallow period in Live Oak, Fl. Weed counts include all living plants independent of visual health. Note x axis dates and treatment applications timelines are not drawn to scale.

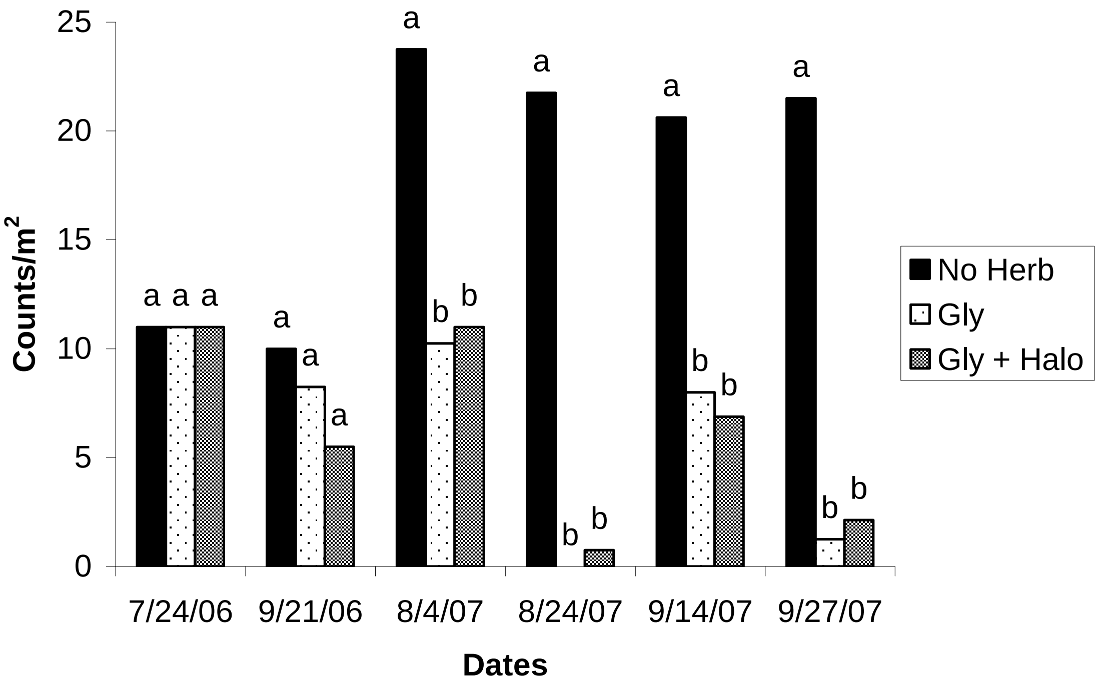


Figure 1-13. Effect of herbicides on hairy indigo counts during the summer 2006 and 2007 fallow period. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Note x axis dates are not drawn to scale.

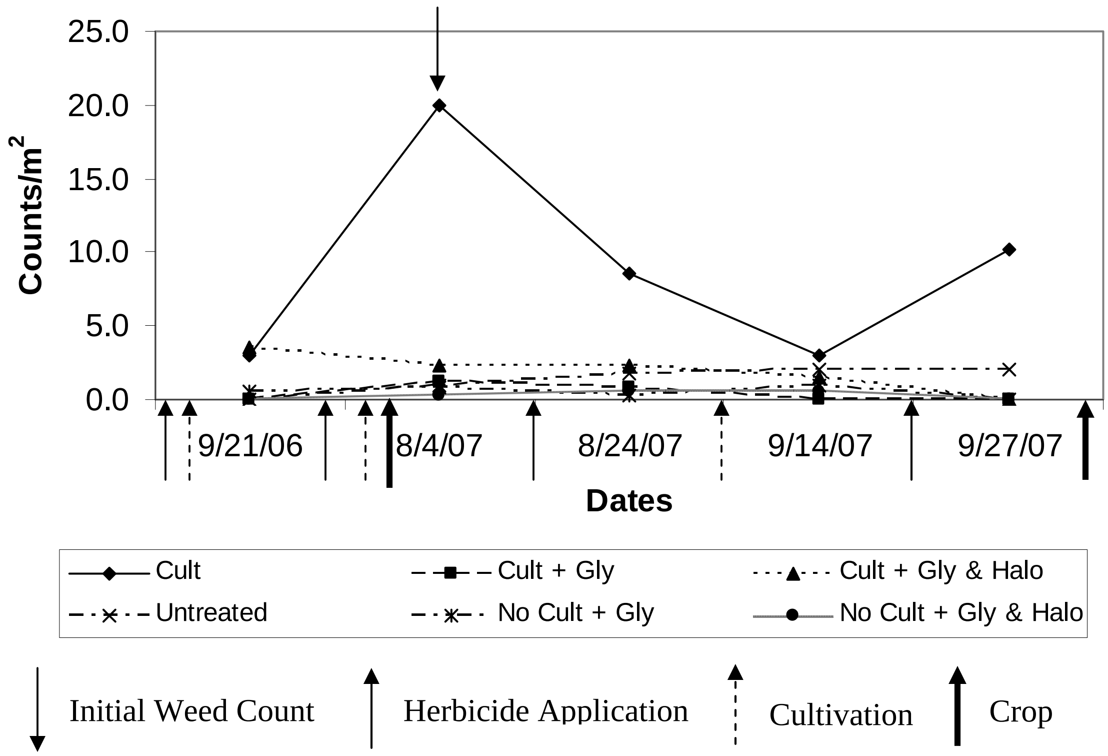


Figure 1-14. Browntop Millet counts during the summer 2006 and 2007 fallow period in Live Oak, Fl. Weed counts include all living plants independent of visual health. Note x axis dates and treatment applications timelines are not drawn to scale.

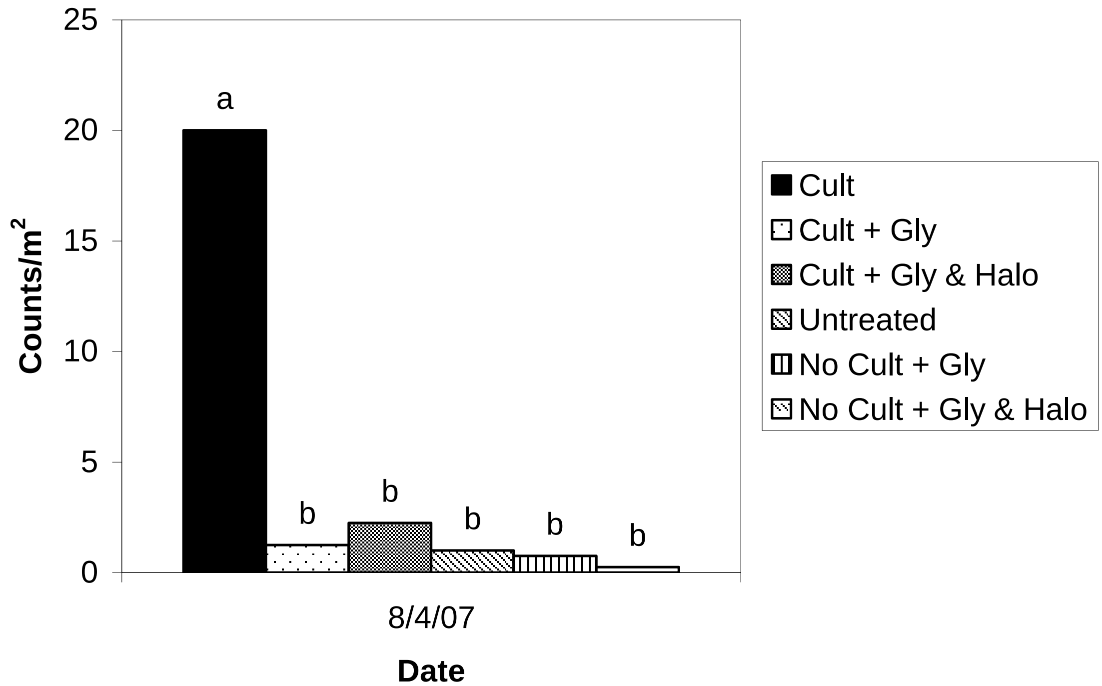


Figure 1-15. Effect of treatment on browntop millet counts during the summer 2006 and 2007 fallow period in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health.

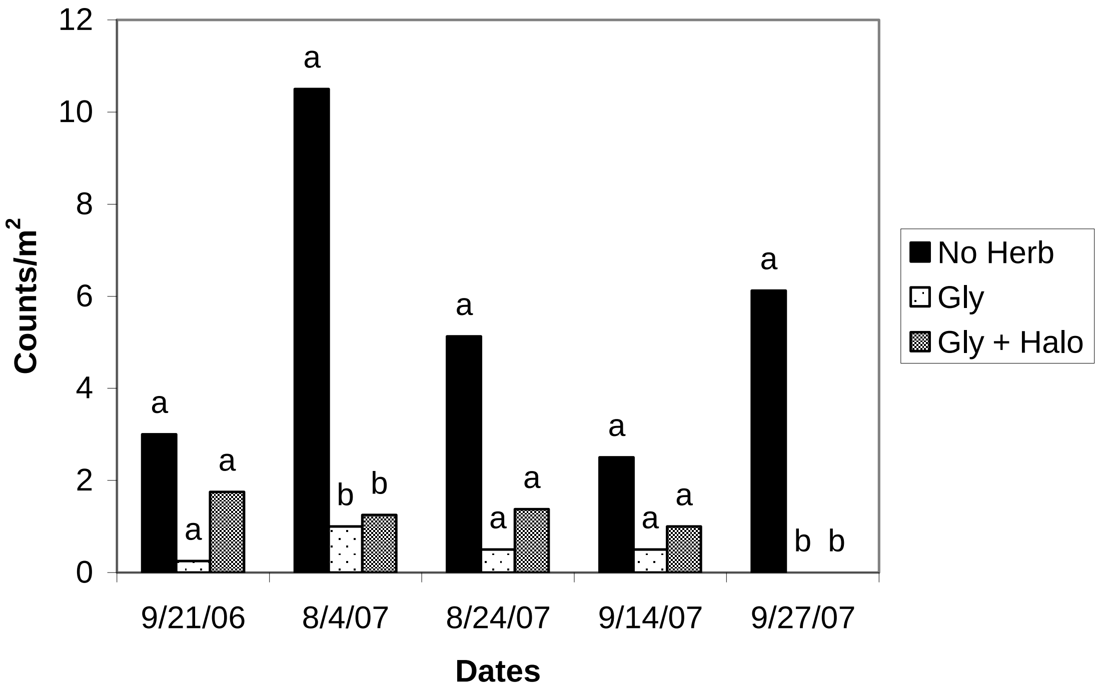


Figure 1-16. Effect of herbicides on browntop millet counts during the summer 2006 and 2007 fallow period. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Note x axis dates are not drawn to scale.

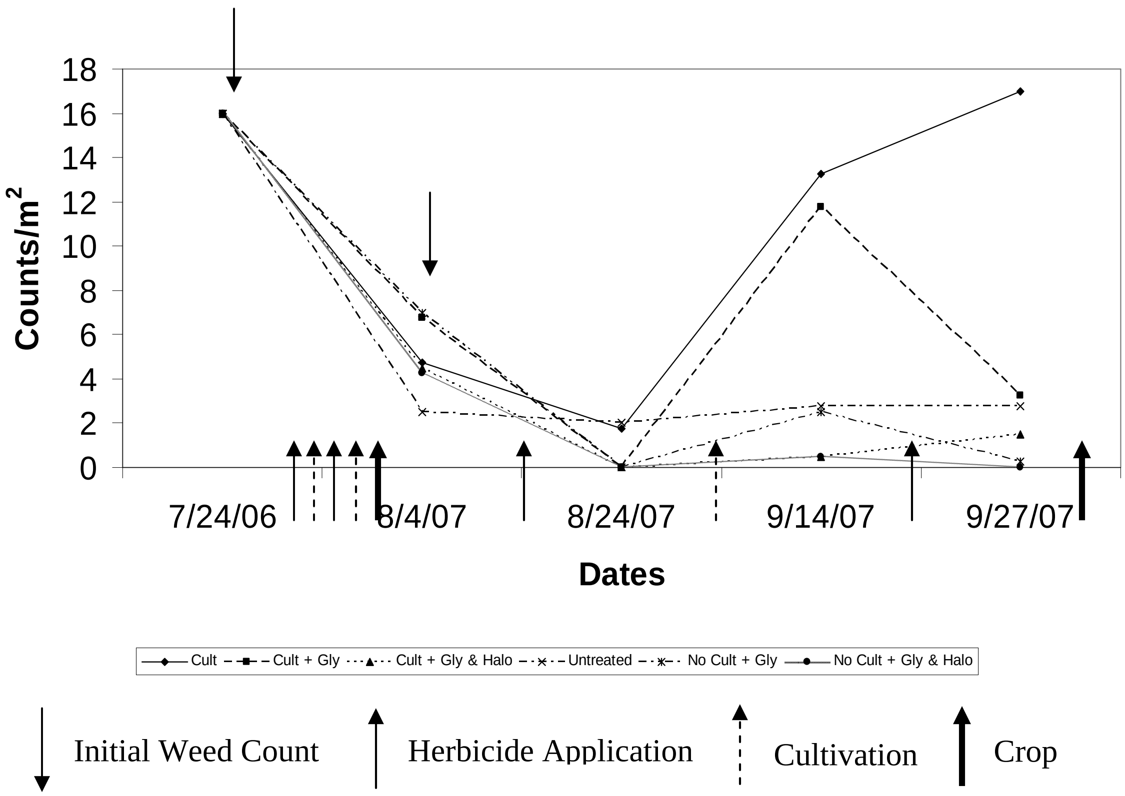


Figure 1-17. Carpetweed counts during the summer 2006 and 2007 fallow period in Live Oak, Fl. Weed counts include all living plants independent of visual health. Note x axis dates and treatment applications timelines are not drawn to scale.

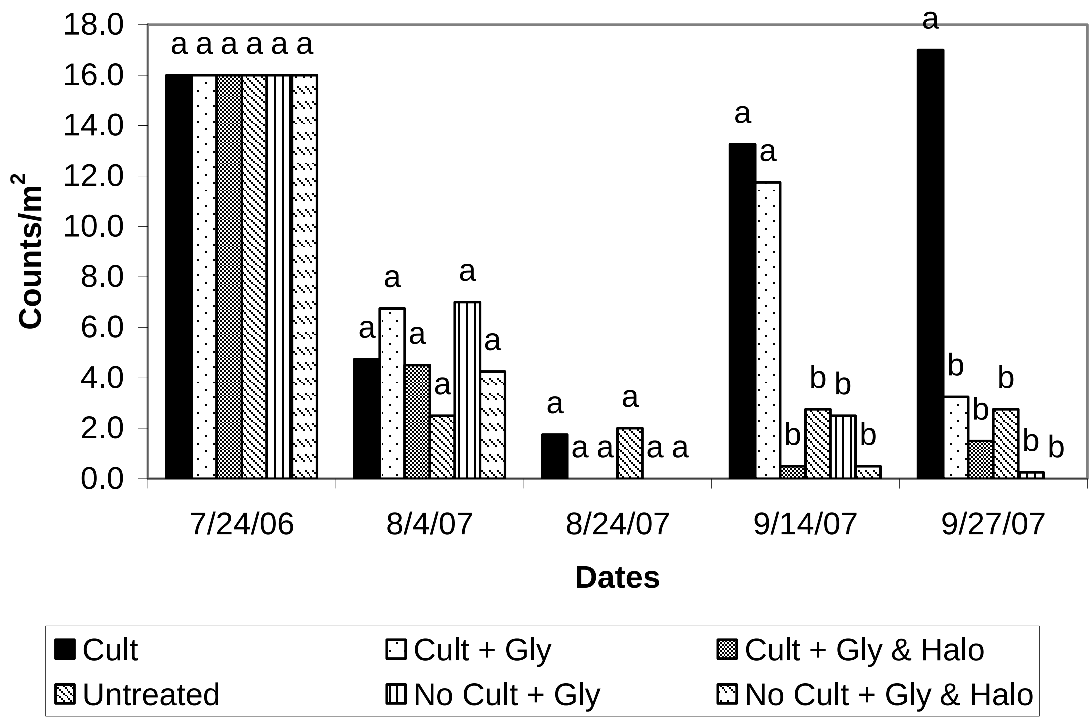


Figure 1-18. Interaction effect of treatment and date on carpetweed counts during the summer 2006 and 2007 fallow period in Live Oak, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Note x axis dates are not drawn to scale.

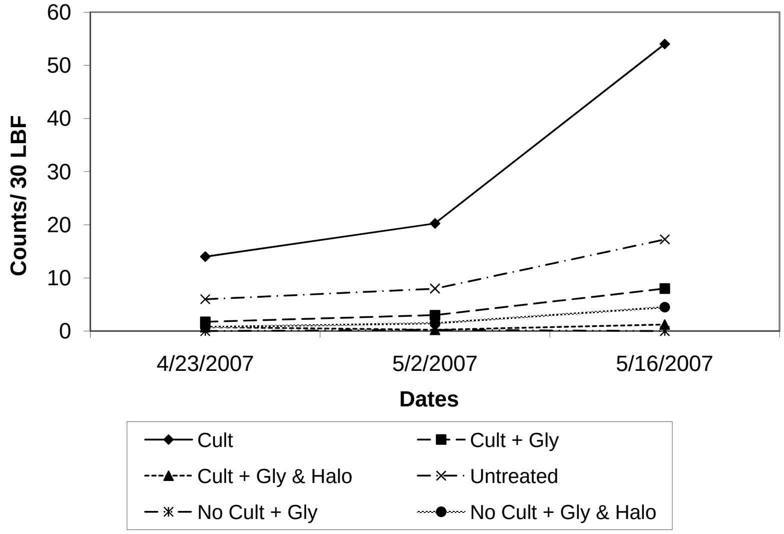


Figure 1-19. Purple nutsedge counts per 30 linear bed feet of row within a bell pepper crop during the spring of 2007 in Live Oak, Fl. Weed counts include all living plants independent of visual health. Note x axis dates are not drawn to scale.

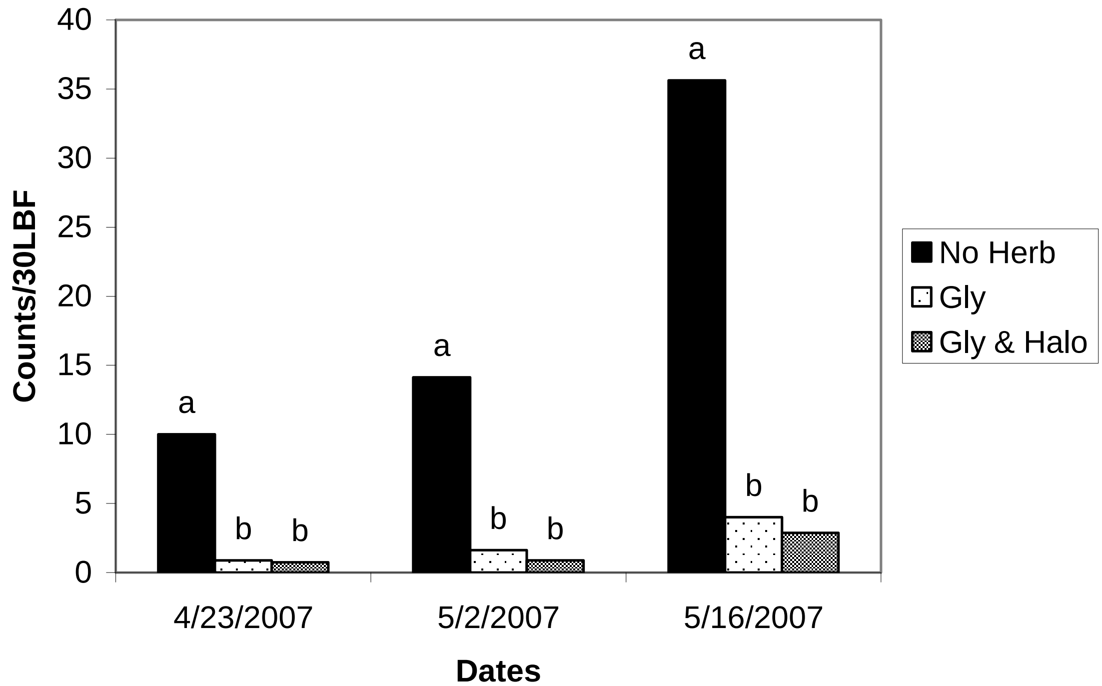


Figure 1-20. Effect of herbicides on purple nutsedge counts per 30 linear bed feet within a bell pepper crop during the spring of 2007 in Live Oak, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Note x axis dates are not drawn to scale.

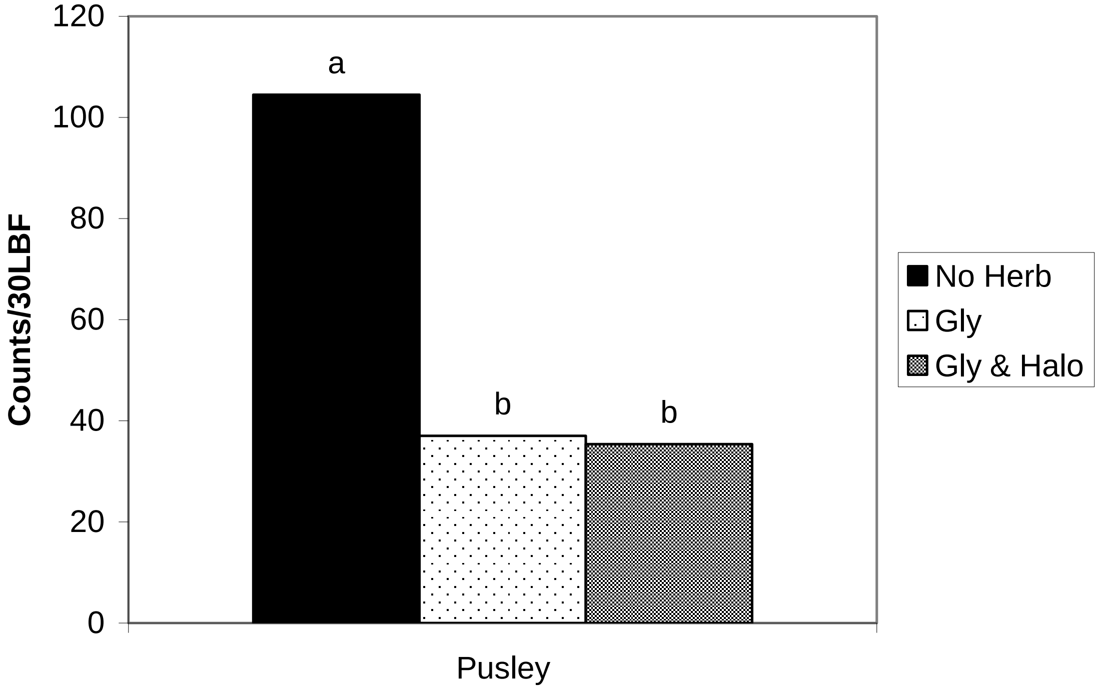


Figure 1-21. Effect of herbicides for Florida pusley counts located in the planting holes per 30 linear bed feet within a bell pepper crop during the spring of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health.

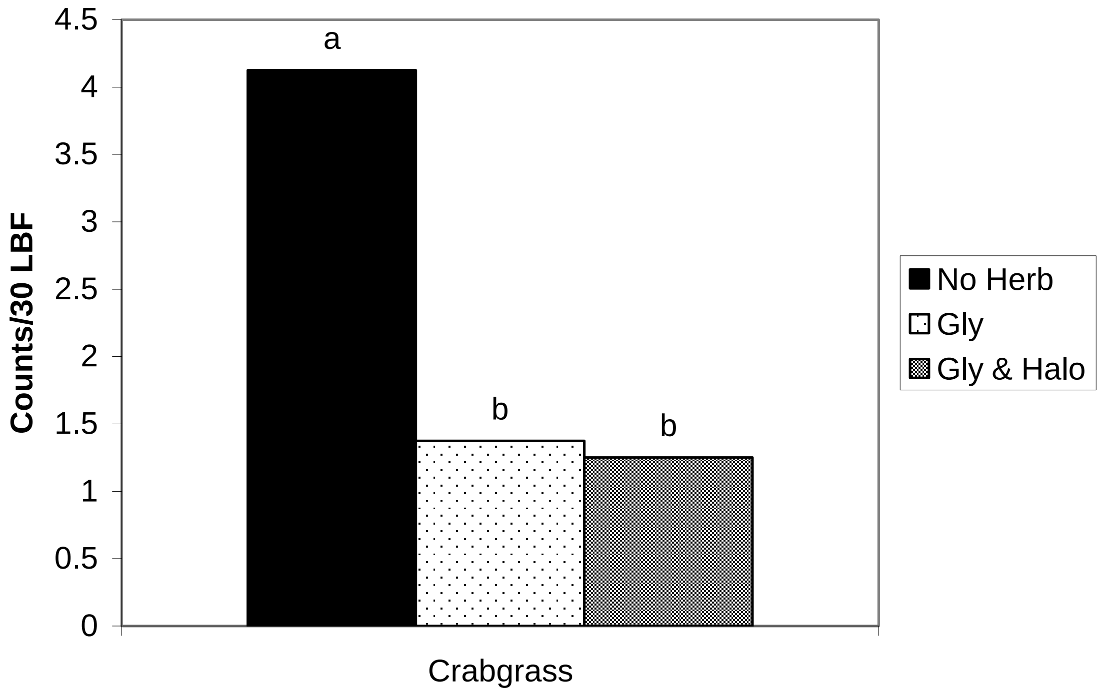


Figure 1-22. Herbicide main effect for crabgrass counts per 30 LBF within the rows of a pepper crop during the spring of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health.

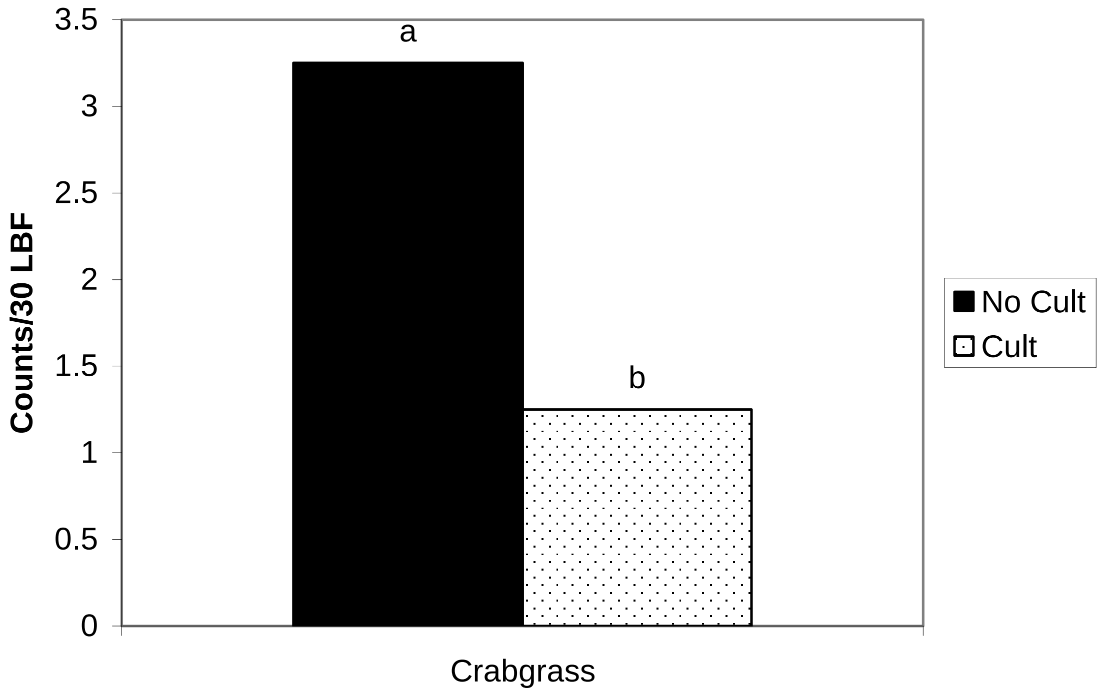


Figure 1-23. Cultivation main effect for crabgrass counts per 30 LBF within the rows of a pepper crop during the spring of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health.

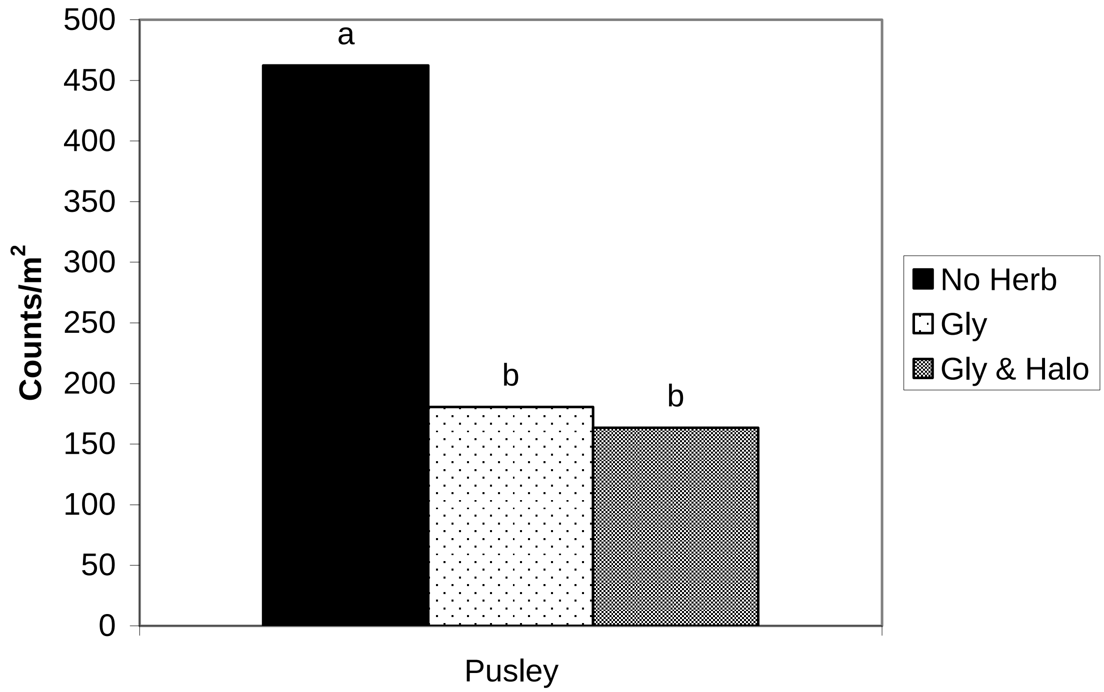


Figure 1-24. Herbicide main effect for Florida pusley counts per m^2 located within the row middle of a pepper crop during the spring of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health.

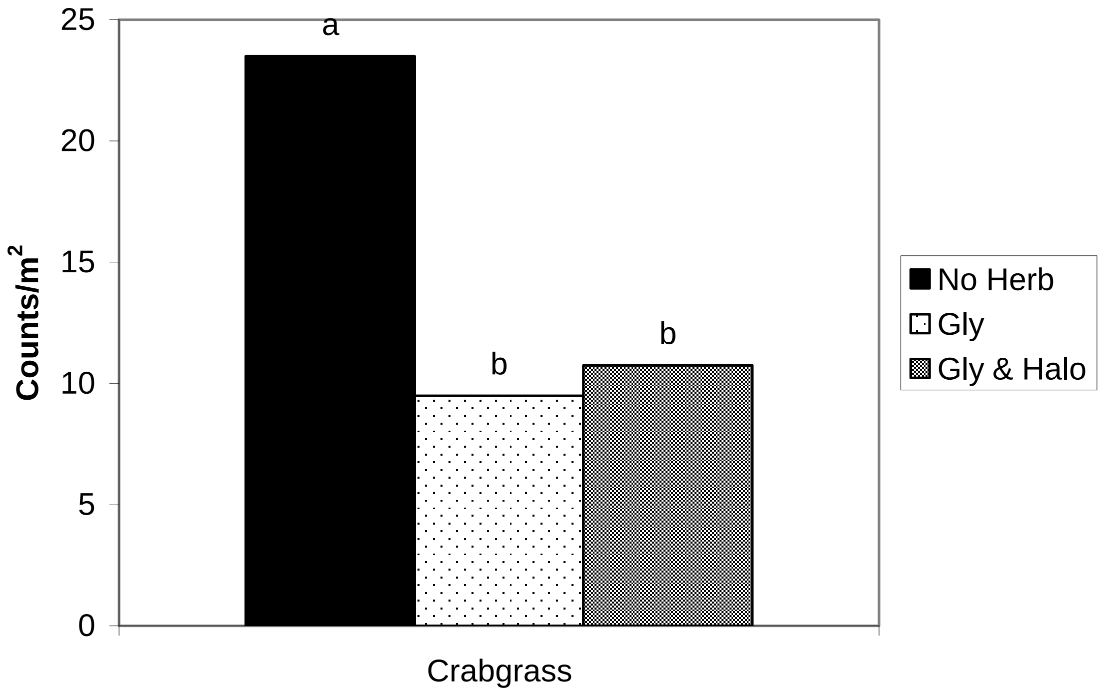


Figure 1-25. Herbicide main effect for large crabgrass counts per m^2 located within the row middle of a bell pepper crop during the spring of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health.

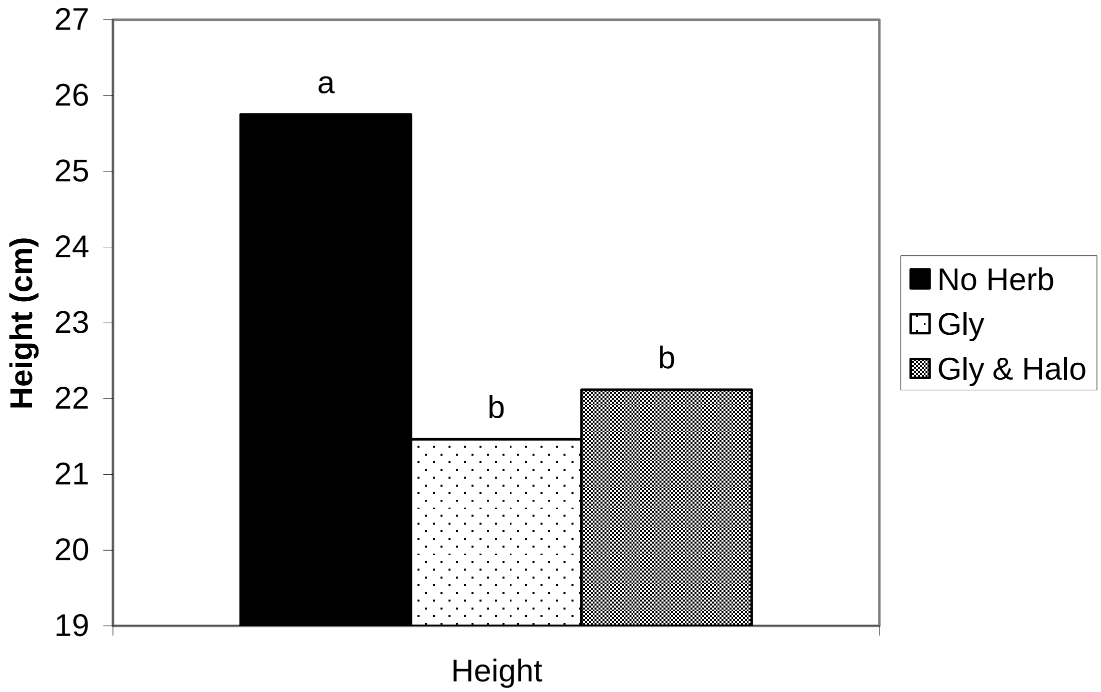


Figure 1-26. Herbicide main effect for the average of six bell pepper heights in cm during the spring of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05.

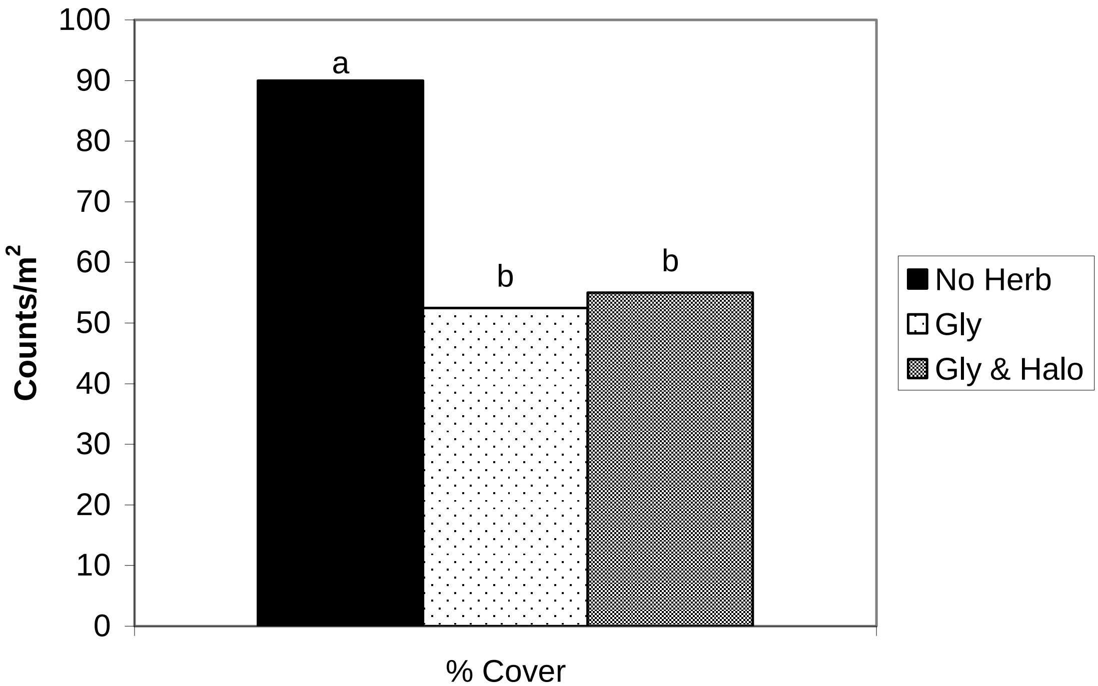


Figure 1-27. Herbicide main effect for the overall percentage of ground cover for all weed species combined in a snap bean crop during the spring of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health.

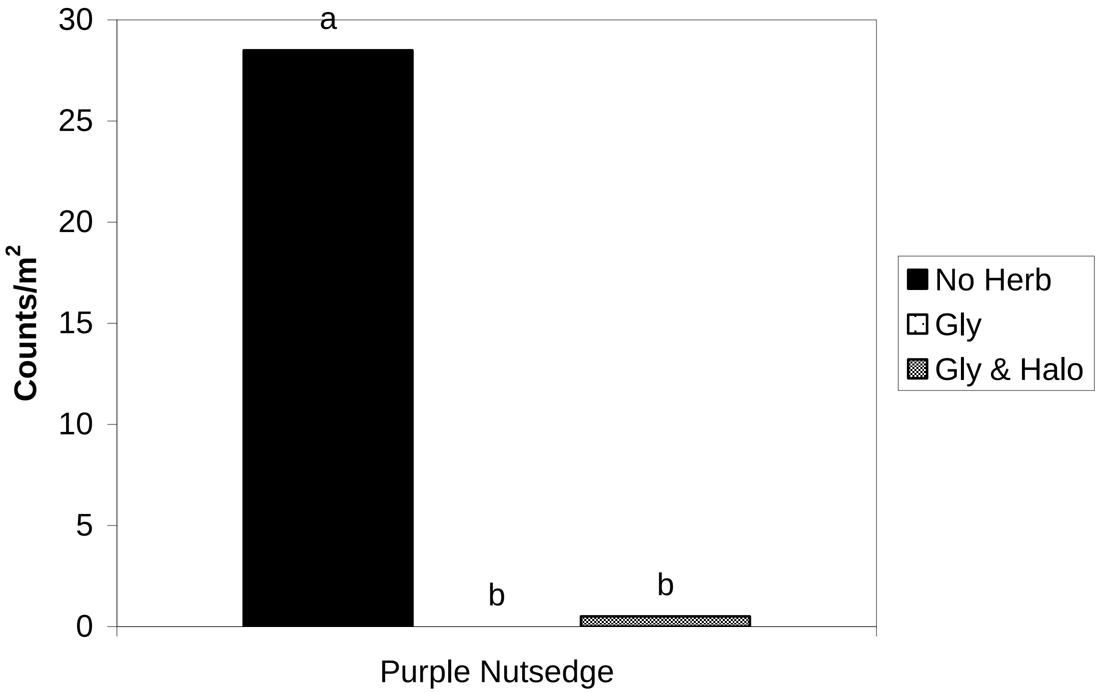


Figure 1-28. Herbicide main effect for purple nutsedge counts per m^2 in the row of a snap bean crop during the spring of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health.

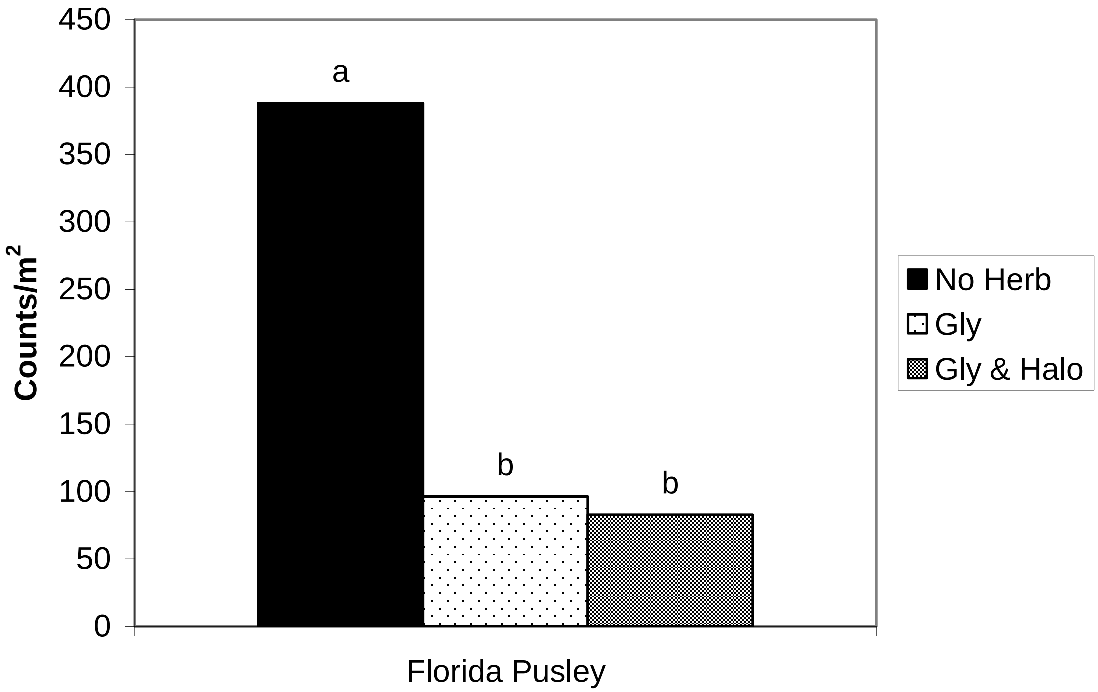


Figure 1-29. Herbicide main effect for Florida pusley counts per m^2 in the row of a snap bean crop during the spring of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health.

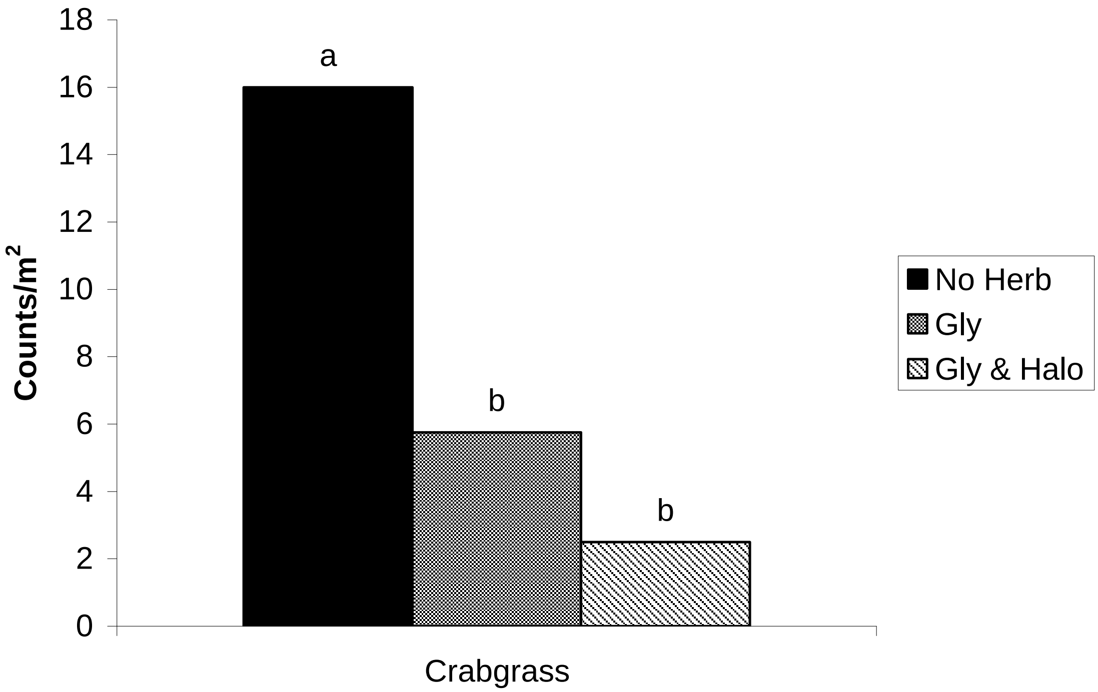


Figure 1-30. Herbicide main effect for large crabgrass counts per m^2 in the row of a snap bean crop during the spring of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health.

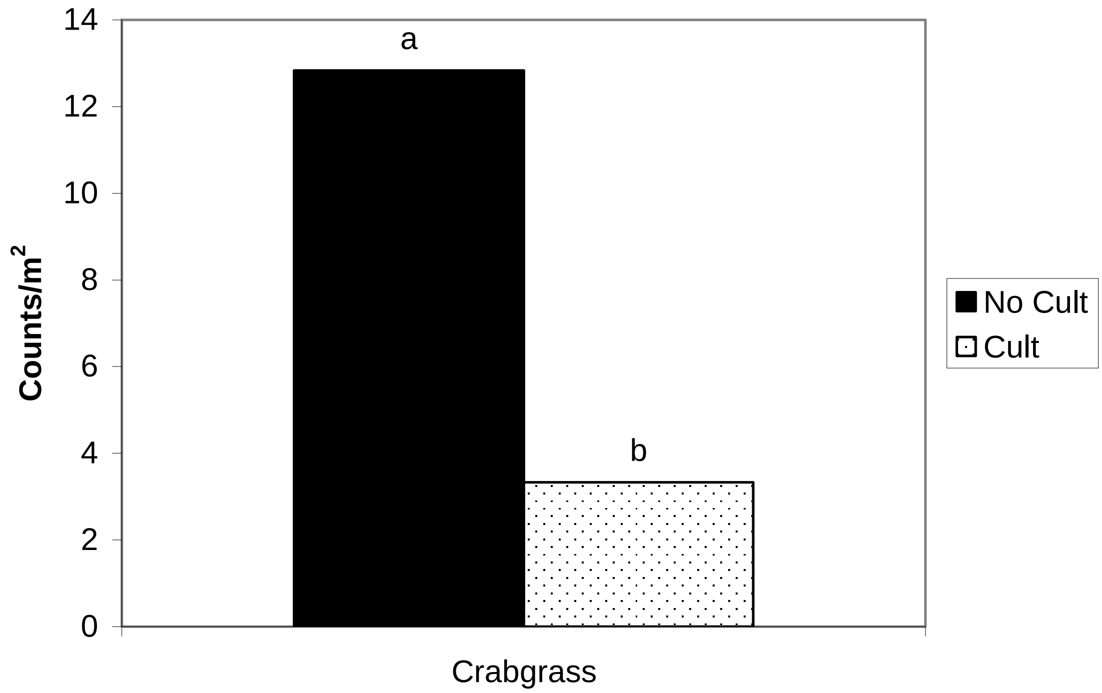


Figure 1-31. Cultivation main effect for large crabgrass counts per m^2 in the row of a snap bean crop during the spring of 2007 in Live Oak, Fl. Means followed by the same letter within are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health.

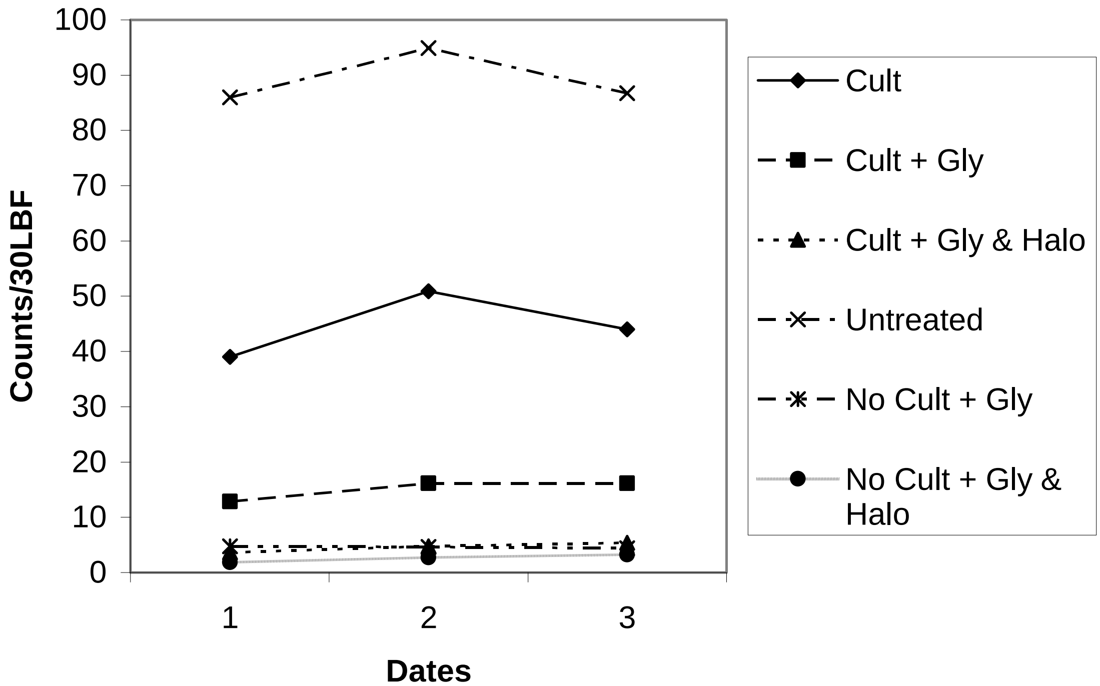


Figure 1-32. Purple nutsedge counts per 30 linear bed feet of row within a bell pepper crop during the fall of 2007 in Live Oak, Fl. Weed counts include all living plants independent of visual health. Note x axis sampling dates were not equally spaced in time.

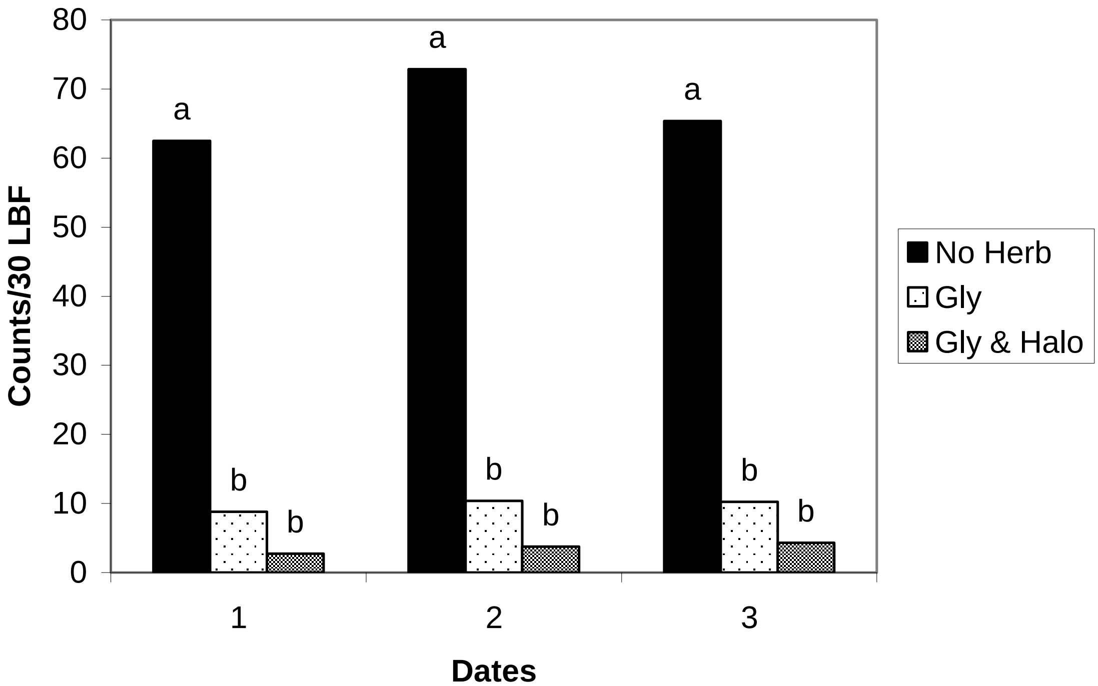


Figure 1-33. Effect of herbicides on purple nutsedge counts per 30 linear bed feet within a bell pepper crop during the fall of 2007 in Live Oak, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Note x axis sampling dates were not equally spaced in time.

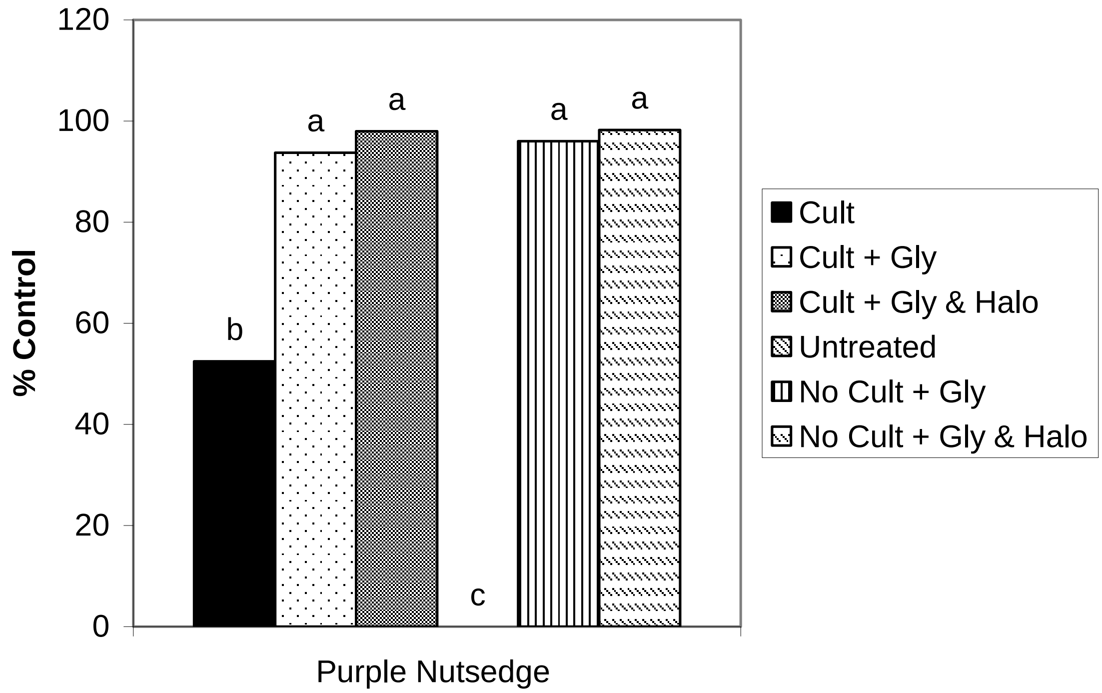


Figure 1-34. Effect of fallow treatments on the control of purple nutsedge in the rows of a cabbage crop during the fall of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

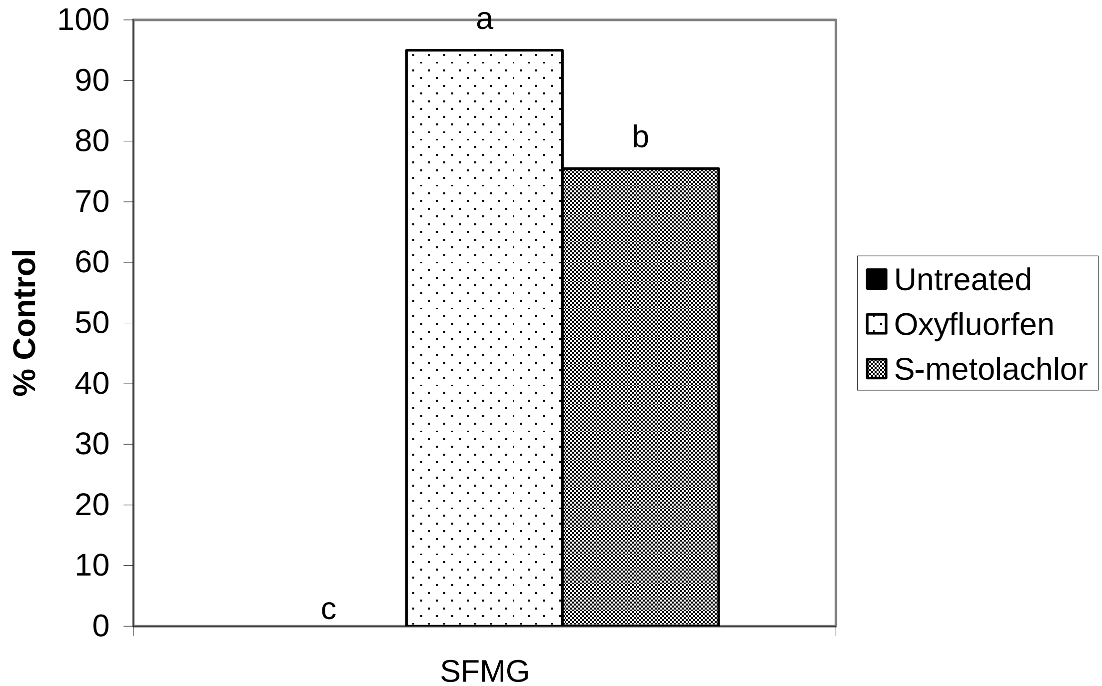


Figure 1-35. Pre plant herbicide main effect for the control of small flower morningglory in the rows of a cabbage crop during the fall of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

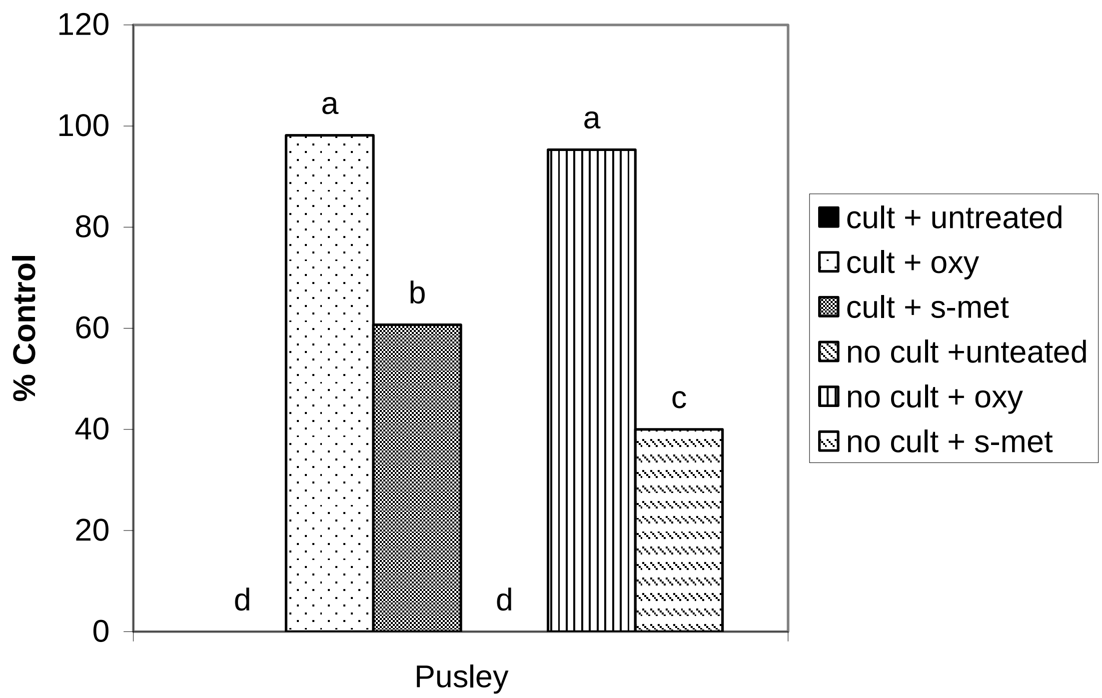


Figure 1-36. Interaction effect of cultivation and pre plant herbicides on the control of Florida pusley in the rows of a cabbage crop during the fall of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

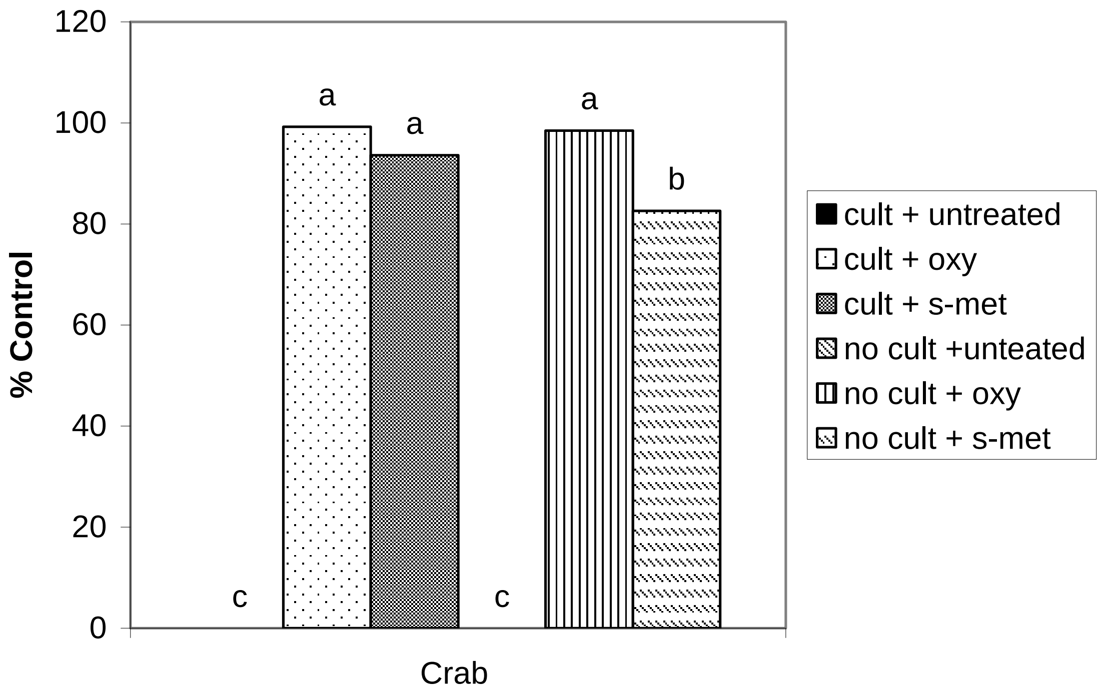


Figure 1-37. Interaction effect of cultivation and pre plant herbicides on the control of large crabgrass in the rows of a cabbage crop during the fall of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

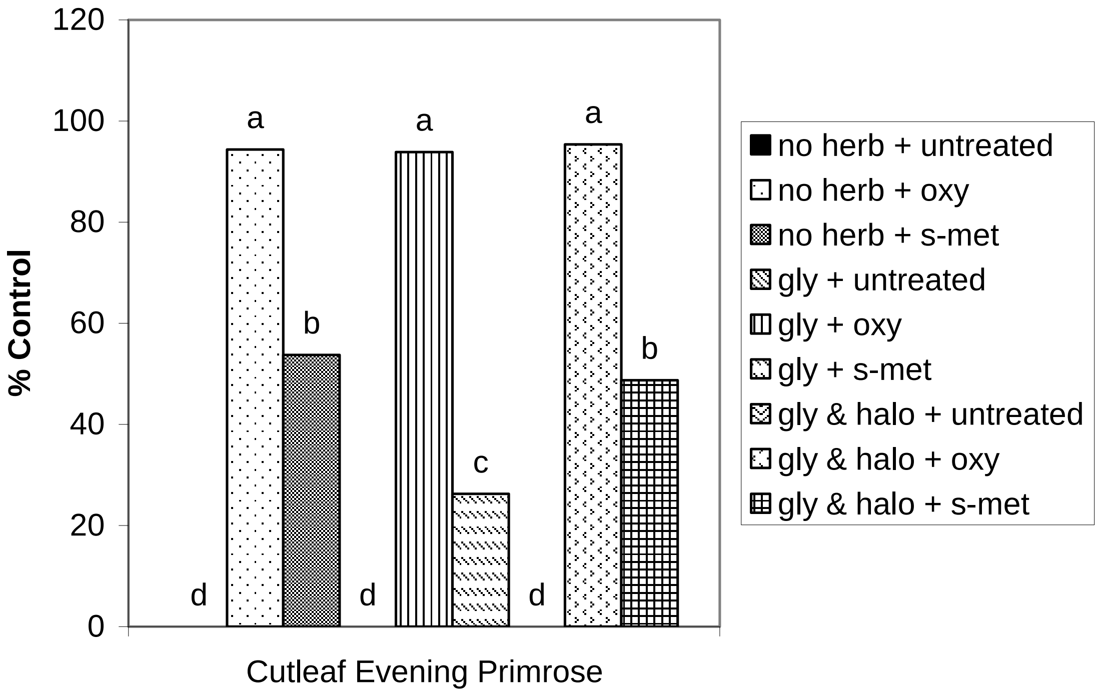


Figure 1-38. Interaction effect of fallow herbicides and pre plant herbicides on the control of cutleaf evening primrose in the rows of a cabbage crop during the fall of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

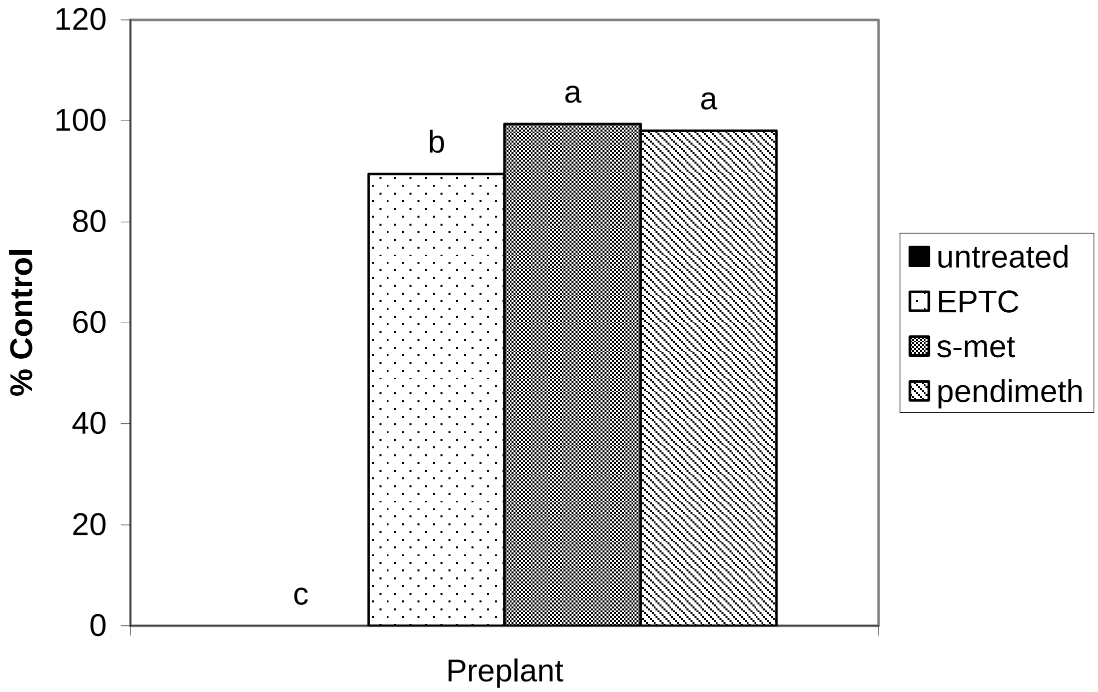


Figure 1-39. Main effect of pre plant herbicides on the control of large crabgrass in the rows of snap beans during the fall of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

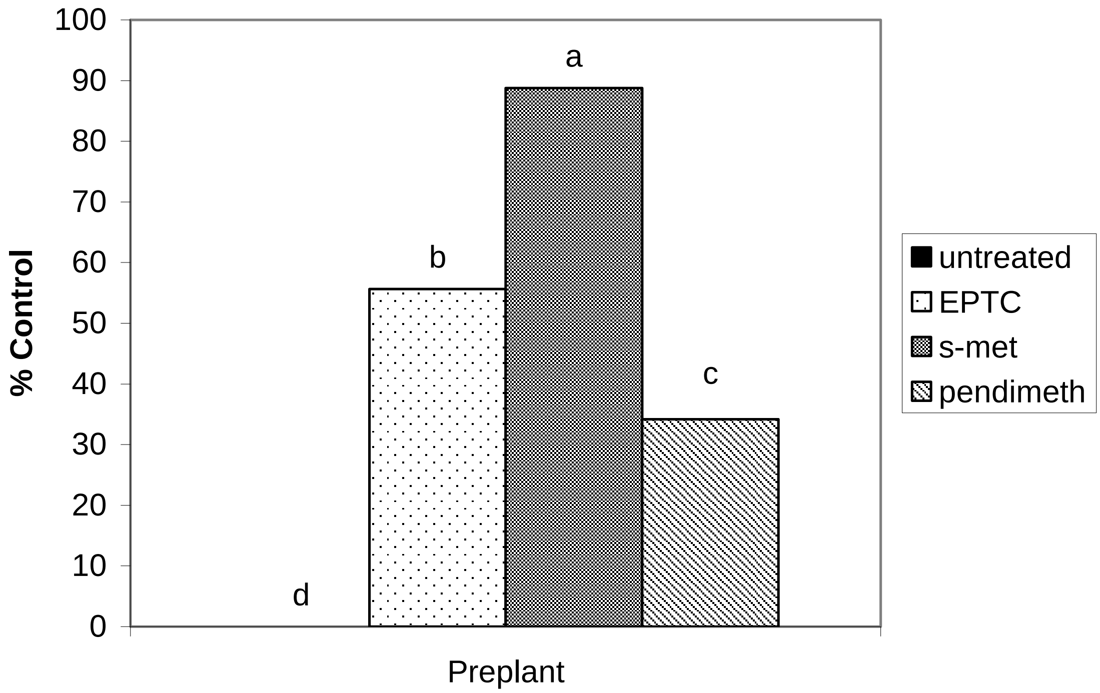


Figure 1-40. Main effect of pre plant herbicides on the control of cutleaf evening primrose in the rows of snap beans during the fall of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05.

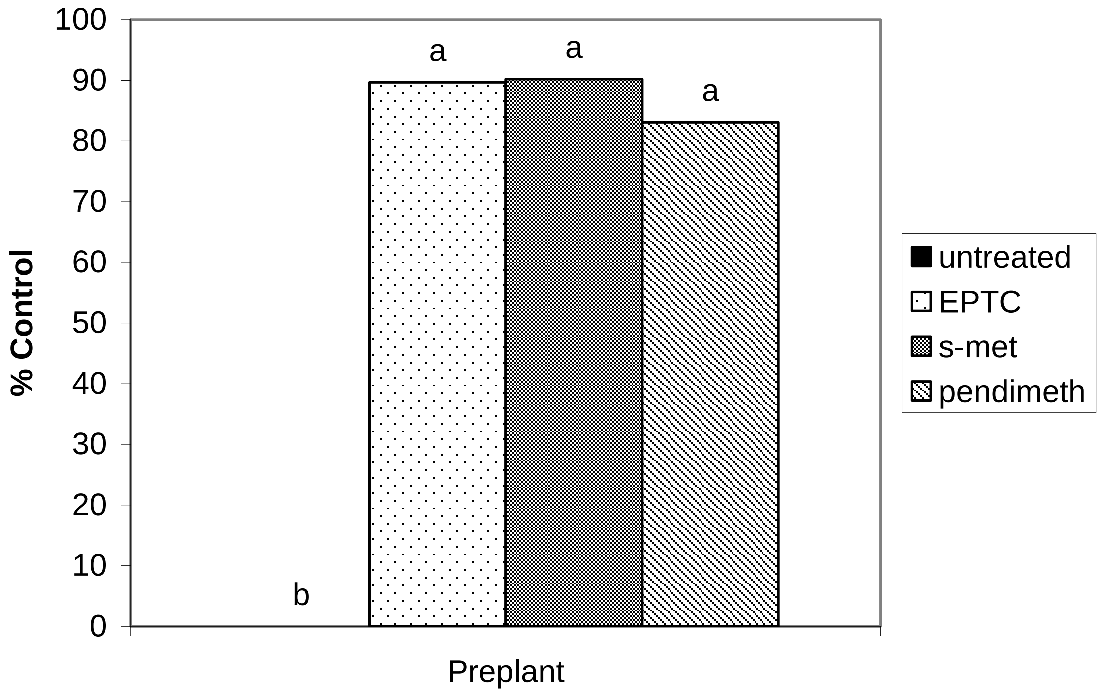


Figure 1-41. Main effect of pre plant herbicides on the control of smallflower morningglory in the rows of snap beans during the fall of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

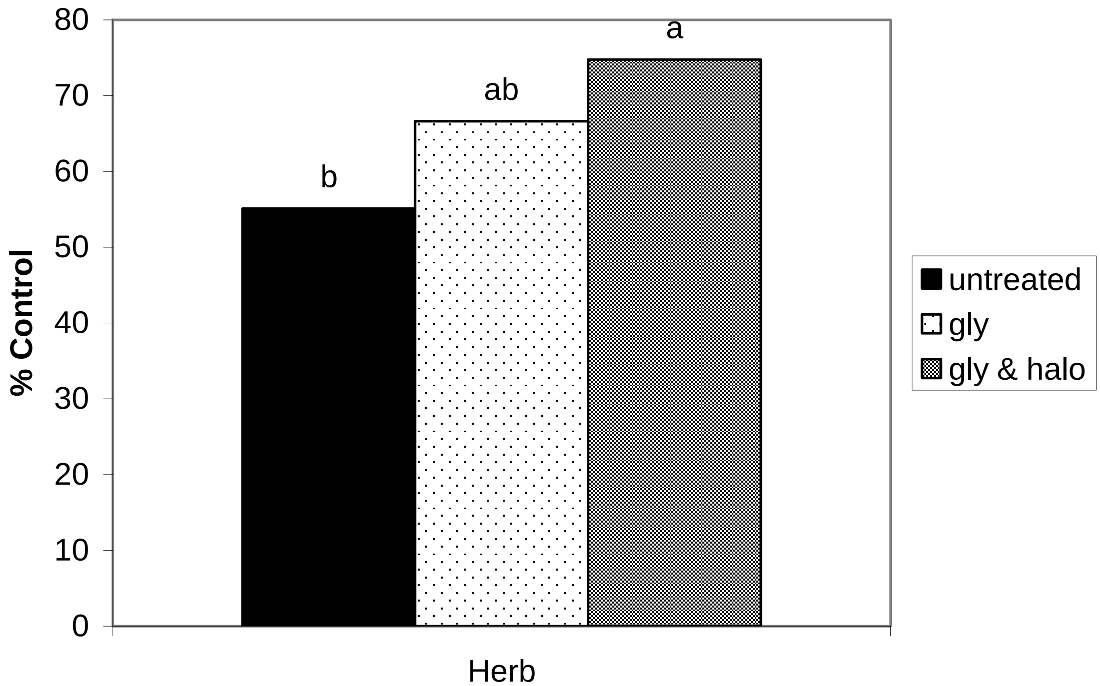


Figure 1-42. Main effect of fallow herbicides on the control of smallflower morningglory in the rows of snap beans during the fall of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

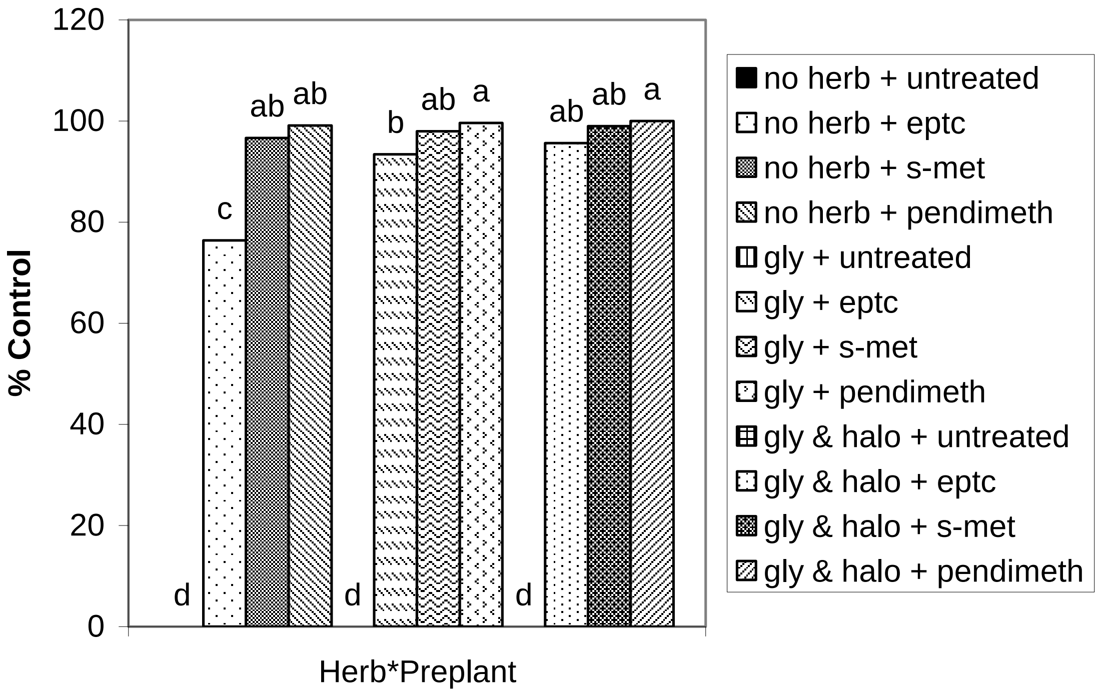


Figure 1-43. Interaction effect of fallow herbicides and pre plant herbicides on the control of Florida pusley in the rows of snap beans during the fall of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

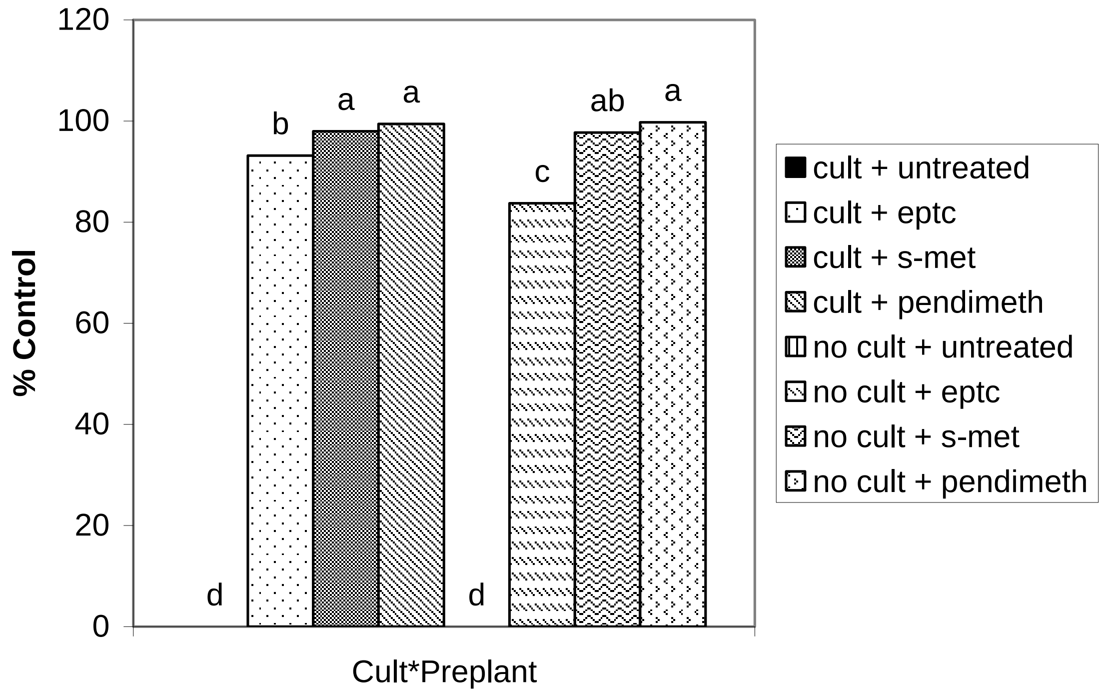


Figure 1-44. Interaction effect of cultivation and pre plant herbicides on the control of Florida pusley in the rows of snap beans during the fall of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

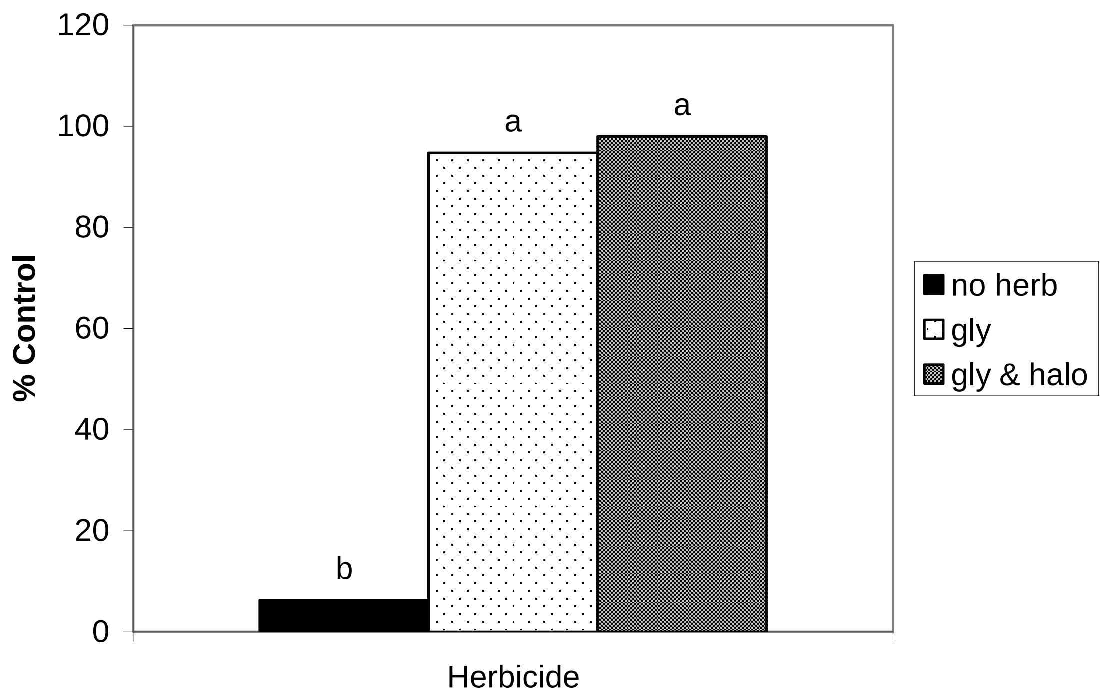


Figure 1-45. Main effect of fallow herbicides on the control of purple nutsedge in the rows of snap beans during the fall of 2007 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

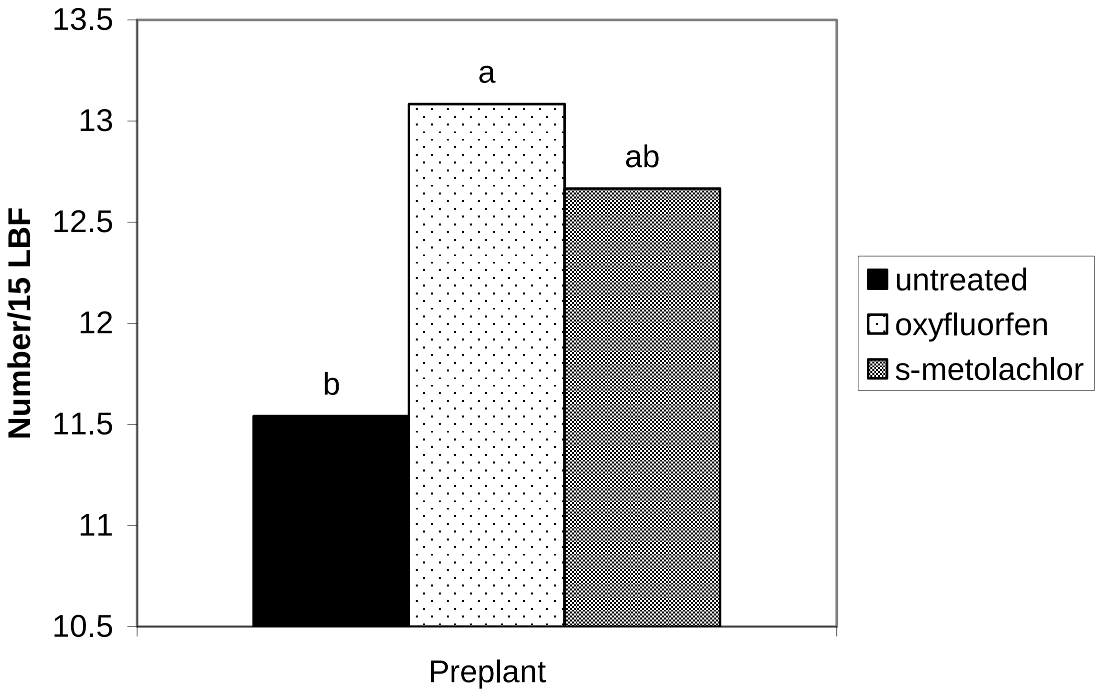


Figure 1-46. Main effect of pre plant herbicides on the number of cabbage per plot (15 LBF) during the winter of 2008 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05.

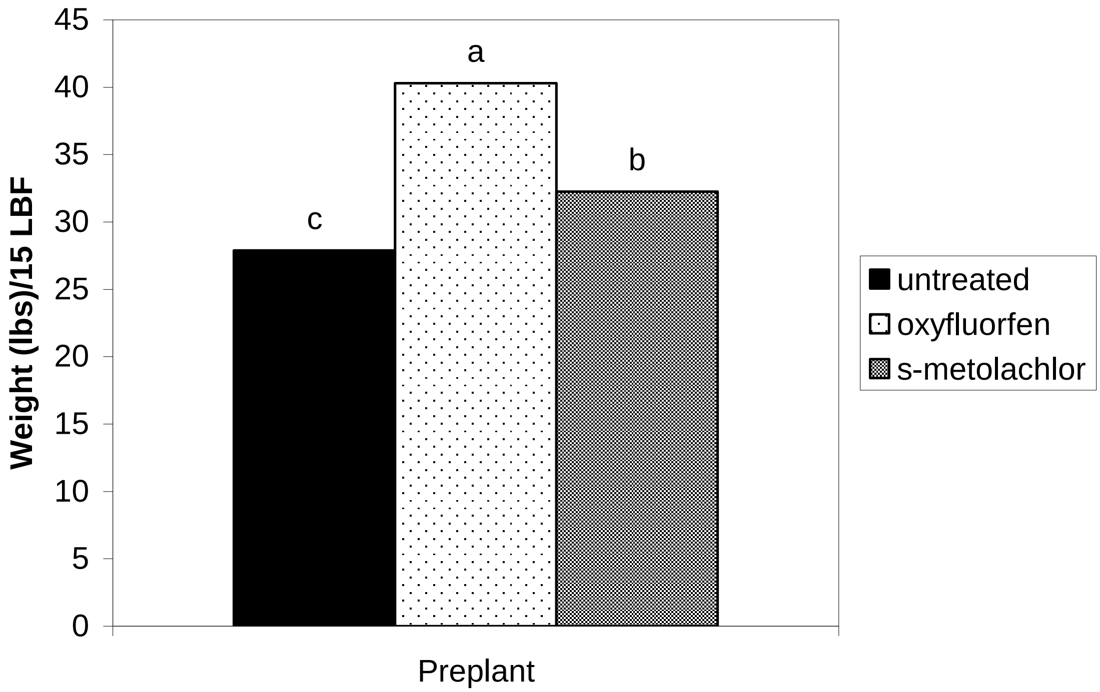


Figure 1-47. Main effect of pre plant herbicides on the total cabbage weight during the winter of 2008 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher’s Least Significant Difference test at P = 0.05.

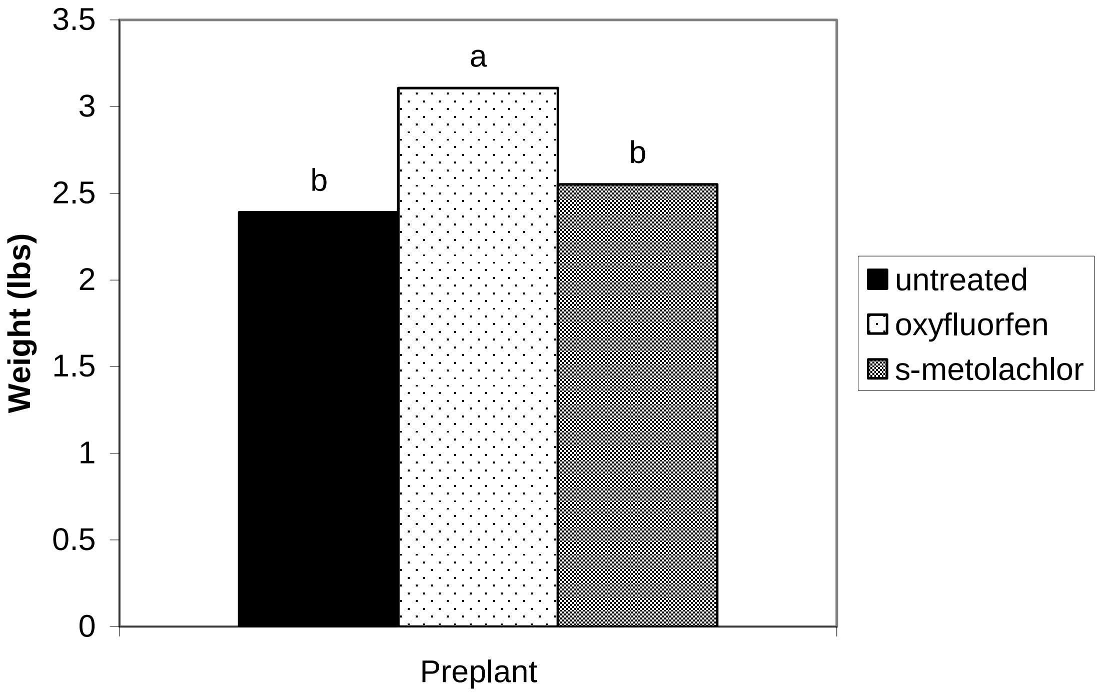


Figure 1-48. Main effect of pre plant herbicides on the average cabbage weight during the winter of 2008 in Live Oak, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05.

CHAPTER 3
FALLOW EXPERIMENT – CITRA, FL LOCATION

Objective

The objective of this experiment was to investigate the efficacy of several herbicides (including pre, post, contact, and systemic materials) and cultivation on fallow weed control and subsequent crop yields for several vegetables grown in Florida. In addition, pre-plant herbicides within the crop were investigated to determine which pre-plant herbicide would be most efficacious in conjunction with fallow treatments to provide the best weed control and the highest crop yields.

Materials and Methods

A two year study was conducted at the Plant Science Research and Education Unit in Citra, FL to investigate several fallow treatments on weed control. The setup of the experiment was a randomized complete block design. The treatments were applied twice per fallow season for two consecutive years. The fallow treatments included: 1) an untreated check 2) glyphosate followed by glyphosate 3) glyphosate and metolachlor tank-mixed followed by glyphosate 4) glyphosate and trifloxysulfuron tank-mixed followed by glyphosate 5) paraquat and metolachlor tank-mixed followed by paraquat 6) paraquat and trifloxysulfuron tank-mixed followed by paraquat 7) paraquat followed by paraquat and 8) cultivated control. After the first herbicide application the field was left undisturbed (in order to allow the herbicides action to take effect and to take weed control ratings and weed counts) before the second herbicide applications were made. The treatments were replicated 4 times. Plot sizes were strips 5 wide by 30 ft long. The orientation of the length of the plots ran from east to west.

All herbicides were applied with a non-ionic surfactant at a rate of .25 % volume/volume. Glyphosate treatments received the equivalent of 2pt/A using a product that contained 5 pounds per U.S. gallon of glyphosate acid equivalents. Metolachlor treatments were applied at rate of 1.25 pt/A using a product that contained 7.62 pounds of active ingredient per gallon. Trifloxysulfuron was sprayed at a rate of 0.2 oz wt/A from a product that contained 75% active ingredient. Paraquat was applied at a rate of 3 pt/A using a product that contained 2 pounds of active ingredient per gallon.

Fallow Measurements

Two measurements were taken for each treatment plot; the percent weed control provided by that fallow method and weed counts for each individual species. Percent control is defined as the amount of control provided by each treatment compared to the untreated check in which no fallow treatments were implemented. Therefore by definition the untreated check provided zero percent control, because there was no weed control improvement. However, 90 percent control means that there is 90 percent less weeds in that particular area compared to the untreated check. In addition to plant death, weed control ratings took into account the physical appearance of the weeds present. Treatments that resulted in chlorosis, necrosis, and stunting of weeds were rated as providing weed control greater than that of the untreated check.

Weed counts were taken in a .5 m^2 (.5 meters wide by 1 meter long) rectangle constructed of PVC pipe. Counts accounted for all living weeds in the area regardless of their physical condition; therefore weed counts provided information only pertaining to plant death or reduction in numbers provided by the different fallow treatments. In addition, weed counts provided a base level of weeds present in the untreated check plots on which to compare, contrast, and extrapolate the effect of the % weed control ratings for the other fallow treatments. Weed counts were only made during the second fallow season. During the first fallow season only the cultivated treatment areas were tilled during the fallow season, however during the second fallow season all the fallow treatment areas were tilled. During the second year the cultivated treatment plots were hand hoed every other week during the cropping season in addition to being cultivated during the summer fallow.

Crop 1

Sweet corn was planted during the spring after the first summer fallow treatments were applied. The entire field was treated with the same pre-emergence herbicide directly after the crop was planted. Row middles in the plots were visually rated for % weed control for each individual weed species. No differences in yields were recorded between fallow treatment plots, therefore yield data was not included.

Crop 2

Cabbage was planted during the fall after the second summer fallow treatments were applied. The cropping experimental design was a split plot design, where the main fallow plots were split into pre-emergence herbicide treated subplots. There were two pre-plant herbicide treatments; oxyfluorfen and s-metolachlor. The oxyfluorfen was applied to the soil surface prior to planting cabbage transplants. S-metolachlor was sprayed directly over the top of freshly planted cabbage transplants.

Counts per .5 m^2 and % weed control visual ratings were recorded for the primary weed species present within the plots. The cultivated control plots were hand hoed every two weeks, starting two weeks after planting and continuing throughout the rest of the growing season until harvest. A single cabbage harvest was conducted. All cabbage heads larger than a softball were harvested. Cabbage vigor ratings, total yield (lbs) measurements and number of heads per plot were recorded, and average fruit size was calculated. Cabbage vigor ratings took into account the physical appearance of the cabbage plants due to possible herbicide toxicities from either the fallow or pre-plant herbicides.

Post Cabbage Harvest Weed Control

Long term differences in weed control between fallow treatment plots were still evident even after the second crop was harvested. Hence, weed control ratings and weed counts were taken to quantify the level of long term weed control provided by the various fallow treatments on specific weed species.

Statistical Analysis

Weed control ratings, weed counts, and cabbage harvest yield parameters were analyzed in SAS (Statistical Analysis Software). Statistical differences between fallow and pre-plant treatment plot measurements were identified using ANOVA (analysis of variance) using the Proc GLM procedure. Once statistical differences were identified, treatment means were separated using LSD (least significant differences).

Results and Discussion

Fallow Period (Sedges)

Effect of different fallow treatments on purple nutsedge control - year 1

Overall, all herbicide treatments provided better nutsedge control ($\geq$ 35% control) compared to the untreated check (Figure 2-1). In addition, cultivation increased the level of control compared to the untreated check depending on when it was implemented. After the first treatment applications of the first year, there were significant differences in nutsedge control between the different fallow treatment plots (Figure 2-2). Nutsedge control was highest in the plots that were treated with trifloxysulfuron with either paraquat or glyphosate (87.5 and 72.5 % control respectively), cultivation (77.5 % control), and paraquat plus metolachlor (72.5% control). The addition of trifloxysulfuron and s-metolachlor (to a lesser degree) was expected to increase purple nutsedge control beyond that provided by glyphosate or paraquat alone. The level of control provided by paraquat plus trifloxysulfuron (87.5 % control) was higher than glyphosate alone (57.5 % control), glyphosate plus s-metolachlor (55 % control), and paraquat by itself (47.5 % control).

Glyphosate and paraquat were not expected to perform as highly as the tank-mixes at controlling purple nutsedge, since the various herbicides in the tank mix are known to control purple nutsedge and they have different modes of action. Paraquat alone does not usually provide adequate control of purple nutsedge, because it is a contact material that causes burning of the foliage but does not translocate within the plant to systemically control the underground rhizomes and tubers. Paraquat does not control the shoots of purple nutsedge since the apical meristem is often shielded from the spray application by outer layers of older leaves. The control of purple nutsedge in the cultivated check (77.5 % control) was significantly greater than paraquat by itself (47.5 % control). Cultivation is known to induce different nutsedge control responses. When tillage is implemented during the warm weather when it is dry, purple nutsedge plants do not re-establish themselves after the mechanical disturbance. Under these conditions, nutsedge tubers are exposed to the soil surface, which causes them to desiccate or freeze and die (Glaze, 1987). However, when cultivation is done under warm, moist conditions the plants are able to reestablish themselves after the soil disturbance. Often times, cultivation increases the number of nutsedge plants because it breaks apart the extensive system of underground tubers and rhizomes and thus releases the tubers from dormancy caused by apical dominance. In other words, cultivation may kill or propagate nutsedge depending on the environmental conditions. All the herbicides and cultivation applications resulted in a higher level of purple nutsedge control ($\geq$ 47.5% control) compared to the untreated check.

Two months after the initial fallow applications (when the second fallow applications were made) there were no significant differences between the treatments. Purple nutsedge control declined in the herbicide and cultivation treatments, because the nutsedge population had begun to rebound during the period of inactivity. After the second fallow applications of the first year were applied there were significant differences in nutsedge control between treatments. The application of paraquat plus trifloxysulfuron or s-metolachlor (90 and 82.5 % control respectively), and glyphosate alone (85 % control) resulted in the highest level of purple nutsedge control. The level of control provided by paraquat tank mixed with trifloxysulfuron (90 % control) was significantly higher than glyphosate plus metolachlor (72.5 % control), glyphosate plus trifloxysulfuron (72.5 % control) and paraquat by itself (75 % control). However, the level of nutsedge control provided by the all herbicides and their combinations was excellent ($\geq$ 72.5 % control). The control provided by all the herbicides increased dramatically after the second application ($\geq$ 72.5 % control) compared to the original application ($\geq$ 47.5 % control), especially for glyphosate (increased from 57.5% to 85% control) and paraquat applied alone (control increased from 47.5% to 75%). Nutsedge control was significantly better in all the herbicide treatments ($\geq$ 72.5 % control) compared to the untreated check and the cultivation check. Purple nutsedge control in the cultivated check was nullified due to inactivity. Although cultivation provided initial purple nutsedge control, the population quickly recovered to original levels. Cultivation needs to take place regularly to keep purple nutsedge from becoming reestablished. Once cultivation has ceased, then purple nutsedge is able to multiply without restrictions. However, certain herbicides, such as trifloxysulfuron can provide residual control of purple nutsedge.

Five months after the application of the second fallow treatments (just prior to planting the spring crop), there were still significant differences between treatments. Trifloxysulfuron tank-mixed with either glyphosate or paraquat (87.5 and 77.5 % control respectively), s-metolachlor plus glyphosate or paraquat (82.5 and 70 % control respectively), glyphosate alone (70 % control), and cultivation (71.25 % control) resulted in the highest purple nutsedge control just before planting a spring crop of corn. Trifloxysulfuron plus either glyphosate or paraquat (87.5 and 77.5 % control) and glyphosate plus metolachlor (82.5 % control) provided significantly better control of purple nutsedge than paraquat by itself (55 % control). All the herbicides and cultivation methods resulted in significantly higher nutsedge control ($\geq$ 55 % control) when compared to the untreated check. As discussed earlier, chemical control of purple nutsedge control requires the use of systemic herbicides such as trifloxysulfuron and glyphosate. The efficacy of post emergent herbicides on purple nutsedge may be increased with the addition of a pre-emergent herbicide, such as s-metolachlor. In addition, cultivation provides temporary control of purple nutsedge under dry conditions. Paraquat provides burndown control of purple nutsedge, but shoot re-growth from the tubers and meristem ensue.

Effect of different fallow treatments on purple nutsedge control - year 2

Throughout all of the second year all of the herbicides consistently controlled purple nutsedge better than the untreated and cultivated check (Figure 2-3). The only sampling date when the cultivated check provided better control of purple nutsedge than the untreated check was at the beginning of the season before the treatments were applied, indicating that cultivation from the previous fallow extended control into the second year.

There were significant differences in purple nutsedge control between treatments during the second year of fallowing in Citra. After the first herbicide application during the second year, all the herbicide treatments, except for glyphosate and paraquat alone controlled purple nutsedge better than the untreated and cultivated checks. All the herbicides provided similar nutsedge control.

After tilling the field for the first time during the second fallow season, all the herbicides, except for glyphosate alone controlled purple nutsedge better than the untreated and cultivated checks. Trifloxysulfuron treatments controlled purple nutsedge better than glyphosate alone and glyphosate tank mixed with s-metolachlor. Paraquat alone and paraquat with s-metolachlor controlled purple nutsedge better than glyphosate alone.

Following the second fallow herbicide application during the second year all the herbicide treatments except glyphosate alone controlled purple nutsedge better than the untreated and cultivated checks. In addition, treatments containing trifloxysulfuron controlled purple nutsedge better than glyphosate alone.

All the herbicide treatments, except glyphosate alone controlled purple nutsedge better than the cultivated check and the untreated check. This may be due to the environmental conditions during the first herbicide applications. During the first herbicide applications the plants were drought stressed, which may have decreased the efficacy of glyphosate. In addition, since glyphosate is systemic it takes a longer time to completely control weeds. Although glyphosate did not completely kill purple nutsedge after the second herbicide application, those purple nutsedge plants may eventually die before planting a crop. Adding s-metolachlor to glyphosate seems to improve purple nutsedge control, although not significantly. Paraquat does not typically control purple nutsedge effectively. However, spraying nutsedge with paraquat and cultivating during the summer fallow depleted the carbohydrate reserves in the tubers. In addition, the herbicides were applied when the plants were small and paraquat was able to penetrate the foliage and kill the shoot meristem. The efficacy of paraquat on purple nutsedge, most likely depends on the size of the target weeds. The cultivated check and the untreated check did not differ in their control of purple nutsedge. During the second year the entire field was cultivated across all treatments, therefore we did not expect to observe difference in nutsedge control between the cultivated and untreated check. However, cultivation from the previous year increased purple nutsedge control during the second year, although not significantly. Trifloxysulfuron offered consistently high control of purple nutsedge. Purple nutsedge was controlled by trifloxysulfuron after applications and after tilling between herbicide applications. A long term approach is needed to control purple nutsedge with all of the fallow treatments tested in this experiment.

Purple nutsedge counts - year 2

Overall, if purple nutsedge is left untreated during the fallow season the counts will continue to increase in a linear fashion (Figure 2-5). In addition, cultivating alone increases nutsedge counts throughout the fallow season, but not to the extent of leaving the land idle.

There were no differences in purple nutsedge counts between treatments until the last sampling date during the second fallow season. The untreated check plots contained more purple nutsedge than all the herbicide treated plots (Figure 2-6). Cultivated plots contained similar amounts of purple nutsedge compared to the untreated check and the herbicides treated plots.

Yellow fallow control ratings - year 2

There was a clear separation in yellow nutsedge ratings between the check plots, the paraquat plot and the other herbicide plots during the second year (Figure 2-7). Yellow nutsedge is a bigger plant and has a more upright growth habit compared to purple nutsedge. This may prevent paraquat from contacting the shoot apical meristem directly, as it would in prostrate, which would explain why paraquat provided better control of purple nutsedge.

There were significant differences in yellow nutsedge control between fallow treatments during the second fallow season. After the initial herbicide treatments were applied all the herbicide treatments except for paraquat provided better yellow nutsedge control than the untreated and cultivated checks (Figure 2-8). All the herbicides controlled yellow nutsedge better than paraquat alone. This same pattern was observed after tillage was implemented as well.

However, after the second set of herbicide treatments were applied all the herbicides controlled yellow nutsedge better the untreated and cultivated checks. Treatments containing trifloxysulfuron controlled yellow nutsedge better than glyphosate plus s-metolachlor.

Yellow nutsedge counts - year 2

Yellow nutsedge counts declined dramatically throughout the fallowing period regardless of which treatment was implemented (Figure 2-9). The herbicides and tillage reduced yellow nutsedge during the fallow period. Significant differences in yellow nutsedge counts between treatments were not seen until after the second fallow treatments were applied. All the treatment methods ($\leq$ 3.5 yellow nutsedge/m2) except cultivation alone (5.5 yellow nutsedge/m2) lowered yellow nutsedge counts significantly compared to the untreated control (11 nutsedge/m2) (Figure 2-10). However, cultivation alone resulted in equal levels of yellow nutsedge control as all of the other treatments. Implementing any of these herbicides during the fallow period would be better than leaving yellow nutsedge grow unchecked.

Fallow Period - Grasses

Crabgrass fallow ratings - year 1

After the first year of fallowing all the methods that were implemented to control weeds resulted in a significantly higher level of crabgrass control compared to the untreated check (Figure 2-11). All the herbicides that were applied resulted in the highest level of crabgrass control (≥ 60 % control). Crabgrass control was significantly higher in all the plots that were treated with glyphosate or glyphosate tank-mixes and paraquat plus s-metolachlor (> 81 % control) compared to the cultivated (32.5 % control) or untreated checks. Glyphosate typically provides excellent post-emergent crabgrass control, because it is absorbed systemically and kills the entire plant. S-metolachlor provides excellent pre-emergent control of crabgrass. Paraquat, on the other hand, does not typically provide excellent control of grass, especially when they are bigger because it is not absorbed within the plant and is not able to directly contact the meristem. In grasses, intercalary meristems are located at the base of nodes and leaf blades, which are hard to reach and allow them to re-grow after the top of the plant has been destroyed. This is why grasses are able to re-grow after they have been grazed by herbivores or cut with lawnmowers. Cultivation alone (32.5 % control) controlled crabgrass better than the untreated check. Cultivation is good at controlling crabgrass. However, crabgrass is able to reestablish from rooted stem nodes after cultivation. This is because crabgrass develops a prostrate, crawling growth habit as it becomes mature.

Crabgrass fallow ratings - year 2

Crabgrass control increased incrementally throughout the second year of fallowing when herbicides were applied (Figure 2-12). In other words, crabgrass control increased further after the second application of herbicides were made compared to the first. In the beginning of the second year of fallowing there were no significant differences in crabgrass control between treatments. Therefore, the effect of the first year of fallowing did not carry over to the second year. Crabgrass is an annual weed that is primarily propagated through sexual reproduction and is unlikely to have long term population reductions from one fallow season. In weeds that reproduce sexually there are plenty of seeds in the soil which can germinate when environmental conditions are optimal. A long term approach would be needed to control the deposit of seeds into the soil, and to allow the viable seeds already in the soil to become depleted. On the other hand, weeds such as nutsedge that reproduce asexually through vegetative propagation are more likely to be controlled permanently or more directly through summer fallow treatments. Lastly, the plants were big when herbicides were applied therefore, they were not controlled as well as they would have been if they were small, tender, and more susceptible to herbicides.

After the first fallow weed control methods were applied during the second year, there was a significant difference in crabgrass control between treatment plots. All the herbicide treatments (> 48 % control) were significantly better at controlling crabgrass than the cultivated check (0 % control) or the untreated check (Figure 2-13). When the herbicides were applied they had a direct impact on controlling crabgrass. Remember, all the plots were cultivated during the second year of fallowing, including the untreated check. The reason all treatments were included in case there was carryover from the first fallow season, since the same treatment plots were in the exact same area. This was not the situation with crabgrass control.

One month after implementing the first fallow applications (just prior to applying the second fallow applications), there were still significant differences in crabgrass control between treatments. The treatments that provided the best crabgrass control were glyphosate plus s-metolachlor (47.5 % control) and all the paraquat or paraquat tank-mixes ($\geq$ 42.5 % control). Glyphosate tank-mixed with s-metolachlor (47.5 % control), paraquat plus s-metolachlor (68.8 % control), and paraquat alone (87.5 % control) gave significantly better control than the untreated control, glyphosate by itself (0 % control), glyphosate plus trifloxysulfuron (0 % control), and the cultivated control (0 % control). As described earlier, the first application of herbicides was applied to drought stressed plants, which negatively affected the efficacy of glyphosate in most weeds. However, the addition of s-metolachlor served to control germinating crabgrass seeds during the period after the application. Trifloxysulfuron failed to control crabgrass during the second year. Trifloxysulfuron is labeled to suppress certain grasses, but does not provide control. Paraquat and paraquat tank mixes provided good control of crabgrass after the first fallow application of the second year.

After the second fallow treatments of the second year were applied there were significant differences in crabgrass control between treatments. All of the herbicide treatments provided the same level of control ($\geq$ 87.5 % control), which was significantly higher than the untreated and the cultivated checks (0 % control). The second herbicide applications provided excellent crabgrass control. Environmental conditions were ideal to realize the maximum weed control potential. In addition, the weeds were small because they were all tilled; therefore they were more easily controlled with herbicides.

Crabgrass counts - year 2

Crabgrass counts were low after the initial herbicide application, counts increased after cultivation and then counts decreased again after herbicides were applied (Figure 2-14). This pattern is indicative of what one would expect. Crabgrass is fairly easy to control with herbicides, but once cultivation is performed a flush of germinating seedlings are stimulated to emerge.

There were significant differences in crabgrass counts after the first fallow treatment of the second year. The treatment that provided the best crabgrass suppression was paraquat tank mixed with s-metolachlor (4 crabgrass/m2), which was significantly similar to the untreated check (14 crabgrass/m2), glyphosate plus s-metolachlor (7 crabgrass/m2), glyphosate plus trifloxysulfuron (17 crabgrass/m2), paraquat plus trifloxysulfuron (8.5 crabgrass/m2), and paraquat alone (8 crabgrass/m2) (Figure 2-15). Cultivation plots had the highest crabgrass counts (25.5 crabgrass/m2), which were significantly similar to the untreated check (14 crabgrass/m2), glyphosate alone (20.5 crabgrass/m2), and glyphosate plus trifloxysulfuron (17 crabgras/m2). All the paraquat treatments ($\leq$ 8.5 crabgrass/m2) and glyphosate plus s-metolachlor (7 crabgrass/m2) resulted in significantly lower crabgrass counts than the cultivation alone (25.5 crabgrass/m2). Although cultivation was not performed yet during the second year, prior cultivation events led to an increase in crabgrass numbers by eliminating competition with other plants. Paraquat was very effective at controlling crabgrass. Glyphosate did not perform as well as expected during the first fallow application, which is attributed to drought stressed plants. However, the addition of s-metolachlor did improve the efficacy of glyphosate on crabgrass.

Goosegrass control ratings - year 1

Goosegrass control increased when herbicides and cultivation were implemented and then control decreased slowly after they were implemented (Figure 2-16). Following the first fallow application of the first year there were significant differences in goosegrass control between treatments. Goosegrass was controlled best in all paraquat treatment ($\geq$ 87.5 % control) and glyphosate tank mix ($\geq$ 85 % control) treatment plots (Figure 2-17). S-metolachlor plus either glyphosate or paraquat (97.5 % control) provided significantly better goosegrass control than glyphosate alone (77.5 % control). All fallow weed control methods, including herbicides and cultivation ($\geq$ 30 % control) controlled goosegrass better than the untreated check. All herbicides ($\geq$ 77.5 % control) provided better weed control than the cultivated check (30 % control). All the herbicides provided good post-emergent control of goosegrass. However, the addition of s-metolachlor to either glyphosate or paraquat dramatically increased the pre-emergent control of goosegrass, and therefore increased the overall control of goosegrass.

Two months after the first fallow treatments were applied (prior to applying the second set of fallow treatments) there were still significant differences in goosegrass control between treatment plots. The level of goosegrass control was significantly higher in all the treatments (≥ 35 % control) when compared to the untreated check. The best goosegrass control was obtained from using glyphosate alone (57.5 % control), glyphosate tank mixed with s-metolachlor (67.5 % control), all the paraquat/paraquat tank-mix combinations (≥ 40 % control), and the cultivated check (42.5 % control). Glyphosate plus s-metolachlor (67.5 % control) controlled goosegrass significantly better than glyphosate tank mixed with trifloxysulfuron (35 % control). S-metolachlor provided pre-emergent goosegrass control when added to glyphosate or paraquat but trifloxysulfuron did not. In crabgrass, the same results were observed.

After the application of the second fallow treatments during the first year there was a significant difference in goosegrass control between treatments. All herbicides (100 % control) significantly controlled goosegrass better than the untreated and cultivated checks (0 % control). The weeds were smaller and more susceptible to herbicides during the second application, because the first application killed and burned down the existing weeds. Therefore the herbicides provided more effective control because the targeted weeds were small and more susceptible to control.

Goosegrass control ratings - year 2

Goosegrass was not present in the experimental area the second year until toward the end of the fallowing period. There were significant differences in goosegrass control between treatments during the second year of fallowing. The same pattern was observed in goosegrass control on the last sample date of the second year as the last date during the first year. All the herbicide treatments (100 % control) provided better goosegrass control than the untreated and cultivated checks (0 % control) (Figure 2-18). Consistent control of goosegrass was achieved using two consecutive fallow herbicide applications for both years of the study. The same factors contributed to the increased efficacy of the second herbicide application.

Goosegrass counts - year 2

Goosegrass counts were significantly different between treatment plots during the second year. The untreated (27 goosegrass/m2) and cultivated checks (26 goosegrass/m2) had higher goosegrass counts than the plots treated with herbicides ($\leq$ 0.5 goosegrass/m2), following the last herbicide application of the second year (Figure 2-19). Excellent goosegrass control was obtained by either glyphosate or paraquat without the presence of other herbicides. These results were fairly consistent with the trends found for other grass species.

Corn fallow ratings - year 2

Control of volunteer corn increased throughout the fallow period during the second year in all of the fallow treatment plots, except in the untreated and cultivated check plots, following the spring corn crop (Figure 2-20). Initially there were no significant differences in the control of corn (as a weed) during the off-season at the beginning of year two (Figure 2-21). After the first fallow treatments were applied, there was significantly higher corn control in all of the plots that were treated with herbicides (> 63 % control) compared to the untreated and the cultivated control (0 % control). Controlling volunteer crops during the fallow season is another important reason for implementing weed control methods. Harmful pests, diseases, and viruses can be harbored in volunteer crops during the fallow period. Controlling these crops during the fallow season has the potential to break the disease cycle and lower the intensity of infestation in the subsequent crop. All herbicides tested could be used to adequately control unwanted corn plants between growing seasons.

Crowfootgrass control ratings - year 2

Significant differences in crowfootgrass control were observed between the different fallow weed control methods prior to bed preparation for planting cabbage. All the herbicides (100 % control) used controlled crowfoot grass significantly better than the untreated and cultivated checks (0 % control) (Figure 2-22). The second herbicide application was made to small plants; therefore the level of control provided by the herbicides was excellent. Other grass species responded similarly to the fallow treatments.

Fallow - Broadleaves

Amaranth fallow control ratings - year 1

Amaranth control was very high following herbicide applications and cultivation events during the first year of fallowing (Figure 2-23). The high level of amaranth control was maintained in the trifloxysulfuron treated plots, even between treatment applications. Trifloxysulfuron has shown residual control in many other weed species.

Following the first fallow weed control applications there were significant differences in amaranth control between treatments. All of the treatment methods gave significantly better amaranth control ($\geq$ 90 % control) than the untreated check (Figure 2-24). The plots that were treated with paraquat (by itself or tank-mixed) ($\geq$97.5 % control) or glyphosate tank-mixes (100 % control) had the greatest amount of amaranth control. When glyphosate or paraquat was tank-mixed with either s-metolachlor or trifloxysulfuron (100 % control) it provided amaranth control significantly higher than that provided by glyphosate alone (90 % control) or cultivation (90 % control). The addition, of s-metolachlor and trifloxysulfuron has improved the weed control activity of many other weeds, as well. Adding these herbicides provided a complete range of control including post-emergent control of existing plants and pre-emergent control of germinating seedlings.

A month after the first fallow treatments were applied significant differences in amaranth control were still observed. The highest levels of amaranth control was provided by glyphosate alone (57.5 % control), glyphosate plus trifloxysulfuron (82.5 % control), and paraquat plus trifloxysulfuron (77.5 % control). Glyphosate plus trifloxysulfuron (82.5 % control) controlled amaranth significantly better than glyphosate tank-mixed with s-metolachlor (40 % control), paraquat plus s-metolachlor (37.5 % control), paraquat alone (17.5 % control), cultivation (45 % control), and the untreated check. Similar results were observed for paraquat plus trifloxysulfuron (77.5 % control), except this combination did not significantly control amaranth better than the cultivated check (45 % control). All treatments methods (≥ 37.5 % control), except paraquat alone (17.5 % control), outperformed the level of amaranth control in the untreated check. The addition of trifloxysulfuron certainly improved the duration of amaranth control. In addition, glyphosate controlled amaranth in a persistent manner (complete kill), whereas paraquat on provided temporary control of amaranth (burndown).

After the second fallow herbicide treatments were made there were significant differences in amaranth control between treatments. The herbicide treatment methods (100 % control) all gave better amaranth control than the untreated and cultivated checks (0 % control). All the herbicides are capable of completely controlling amaranth. The timing of application and more specifically the weed growth stage are important factors influencing herbicide efficacy.

Five months after implementing the second fallow herbicide treatments and cultivating (prior to planting the spring crop) all the fallow techniques (≥ 75 % control) provided significantly higher amaranth control than the untreated check. There were no differences between the other treatments, in respect to amaranth control. Cultivation without herbicides gave good amaranth control when it is implemented, but the effects are temporary.

Amaranth fallow control ratings - year 2

During the second year amaranth control was high in the herbicide treated plots after herbicides were applied, and consistently low in the untreated and cultivated checks (Figure 2-25). Similar to the first year of fallowing, trifloxysulfuron treated plots had consistently high amaranth control throughout the entire fallow period; meanwhile the control provided by other herbicides was only temporary.

After the first set of fallow herbicide applications were made during the second year there were significant differences in amaranth control between treatments. The plots that were treated with herbicides ($\geq$ 75 % control) resulted in higher amaranth control than the untreated and cultivated checks (0 % control) (Figure 2-26). All the herbicides ($\geq$ 75 % control) provided similar levels of amaranth control.

After tillage was performed following the first set of fallow herbicide applications there were significant differences in amaranth control between treatments. Trifloxysulfuron tank-mixed with either glyphosate or paraquat (100 % control) controlled amaranth better than the other treatments ($\leq$ 25 % control). This finding was consistent with the results found for amaranth control during the first year of fallowing. In addition, the same trend was observed in many other weeds for both fallowing seasons.

Following the second fallow application of the second year there were significant differences between treatments. Amaranth control was greatest in the areas where herbicides were applied (100 % control) compared to the untreated and cultivated checks (0 % control). Optimum amaranth control was realized when applications were made under ideal environmental conditions to small, succulent, susceptible amaranth seedlings.

Amaranth counts - year 2

Amaranth counts were relatively low in all the plots regardless of treatment after the first fallow treatments were applied (Figure 2-27). Then amaranth counts increased following cultivation. Even after cultivation, amaranth numbers were suppressed in the trifloxysulfuron treated plots. After the second set of fallow herbicide applications amaranth counts decreased again, except in the cultivated and untreated checks. Although cultivation kills the majority of emerged amaranth plants, it does not prevent viable seeds from emerging in the soil. In many cases the opposite reaction is occurs, cultivation often results in a surge of emerging seedlings, especially rudimentary species such as amaranth. However, trifloxysulfuron provided residual control to hinder amaranth emergence even after tillage events.

There were no significant differences in amaranth counts between treatments until after the second treatments were made during the second year. The cultivated (115 amaranth/m2) and untreated checks (64.5 amaranth/m2) contained the highest numbers of amaranth (Figure 2-28). The cultivated check (115 amaranth/m2) had higher numbers of nutsedge compared to the plots treated with herbicides ($\leq$ 3 amaranth/m2). In addition, there was no difference between the amount of amaranth in the untreated check plot (64.5 amaranth/m2) compared to the herbicide treatments ($\leq$ 3 amaranth/m2) or the cultivated check (115 amaranth/m2). All the herbicides gave excellent suppression of emerged amaranth seedlings. Cultivation controlled emerged amaranth, but resulted in a flush of germinating seeds.

Purslane fallow ratings - year 1

Purslane control was very high when the first fallow applications were made, control declined drastically afterward in all plots, except for those treated with trifloxysulfuron, and then control increased dramatically after the second herbicide applications were applied (Figure 2-29). In addition, purslane control dissipated in the cultivation plots throughout the fallow season.

After the first fallow weed control methods were applied there were significant differences in purslane control between the various treatment plots. All the treatments containing paraquat ($\geq$ 97.5 % control) and both the glyphosate tank mixes (with s-metolachlor or trifloxysulfuron) (100 % control) resulted in the highest control of common purslane after the first treatment were applied (Figure 2-30). All the fallow methods resulted in significantly better weed control ($\geq$ 92.5 % control) when compared to the untreated check. In addition, glyphosate tank mixed with either s-metolachlor or trifloxysulfuron and paraquat combined with s-metolachlor provided significantly higher purslane control (100 % control) than the cultivated check and glyphosate alone (92.5 % control). In summary, glyphosate and paraquat provide good control of purslane, but tank-mixing these herbicides with either s-metolachlor or trifloxysulfuron can increase the level of control provided.

One month after the first fallow treatments were applied the first year, there were significant differences in purslane control between treatments. Trifloxysulfuron plus either glyphosate (87.5 % control) or paraquat (75 % control) controlled purslane the best one month after the first fallow treatments were applied. All the treatments except glyphosate by itself (20 % control) provided significantly better control than the untreated check. Glyphosate plus trifloxysulfuron (87.5 % control) gave a significantly greater amount of control than glyphosate alone (20 % control), glyphosate plus s-metolachlor (47.5 % control), paraquat plus s-metolachlor (47.5 % control), paraquat alone (47.5 % control) and cultivation alone (50 % control). Paraquat with trifloxysulfuron (75 % control) gave significantly higher purslane control than glyphosate alone (20 % control).

Trifloxysulfuron provided good residual control of purslane in the period following the first herbicide application.

Following the second fallow treatments of the first year all the herbicides used in the treatments provided significantly higher control (100 % control) than the untreated check and the cultivation check (0 % control). The second herbicide applications were applied to small plants under ideal environmental conditions which allowed the herbicides to provide the maximum level of control.

Purslane fallow ratings - year 2

Purslane control increased throughout the second year of fallowing (Figure 2-31). In addition, a high level of purslane control was established and maintained in the trifloxysulfuron treated plots. At the start of year two, there were not any significant differences in purslane control between treatments. This indicates that there was not residual control of purslane from the first year of fallowing. The lack of residual control between years of fallowing is consistent with many other annual, sexually reproducing weeds.

In the period after the first set of herbicide treatments were applied and cultivation was performed during the second year of fallowing there were significant differences in the level of purslane control between treatments. Trifloxysulfuron plus either glyphosate or paraquat provided significantly higher purslane control (100 % control) than all the other fallow treatments ($\leq$ 20 % control) (Figure 2-32). These findings are consistent with the results found during the first year of the study.

Following the second set of fallow herbicide treatments were applied during the second year there were significant differences between treatments. Purslane was controlled at a significantly higher level where herbicides were applied (100% control) compared to the untreated control and the cultivated check (0 % control). The results found during the second year of fallowing were consistent with the observations made during the first fallow season and are attributed to the same factors.

Purslane counts - year 2

Throughout the second year of fallowing purslane counts declined regardless of fallow treatment, except for cultivation (Figure 2-33). All the plots including the untreated check were tilled during the second year. It is believed that purslane counts were higher in the cultivated check than in the untreated check because there was less nutsedge competition with purslane in the cultivated check compared to the untreated check.

There were no significant differences in purslane counts between treatments after the first fallow applications (both herbicides and tillage) of the second year. After the second fallow herbicide treatments were applied there were significant differences in purslane counts between plots. The cultivated check (108 purslane/m2) contained a significantly higher number of purslane compared to all the other plots ($\leq$ 29 purslane/m2) (Figure 2-34). Purslane count results are in tandem with purslane control results. Cultivation increased the amount of purslane present because it reduced the amount of competition with other weeds such as nutsedge and increased the amount of germinating seeds from the soil seed bank.

Florida pusley control ratings - year 1

At the end of the first year of fallowing there were significant differences in pusley control between treatments. All of the fallowing methods ($\geq$ 77.5 % control) controlled pusley significantly greater than the untreated check (Figure 2-35). These fallow methods provided similar levels of pusley control. These results are consistent with the reaction of other broadleaf weeds to the treatments during year 1.

Florida pusley control ratings - year 2

Florida pusley control increased during the fallow season for all the herbicide treatments (Figure 2-36). After the first fallow treatments (herbicide application followed by cultivation) were applied the second year, there was significant differences in pusley control between treatments. Trifloxysulfuron either tank-mixed with glyphosate or paraquat ($\geq$ 95 % control) provided the greatest level of pusley control (Figure 2-37). Paraquat plus trifloxysulfuron (100 % control) controlled Florida pusley significantly better than glyphosate alone (22.5 % control), glyphosate tank-mixed with s-metolachlor (50 % control), paraquat plus s-metolachlor (22.5 %

control), paraquat alone (0 % control), the untreated check and the cultivated check (0 % control). Glyphosate plus trifloxysulfuron (95 % control) provided the same relative level of control as paraquat tank mixed with trifloxysulfuron (100% control), except that it did not control pusley significantly better than glyphosate plus s-metolachlor (50 % control). Trifloxysulfuron gave excellent residual control of pusley after the plots were cultivated. The other herbicides did not provide control of pusley after the soil was disturbed by cultivation. The untreated control, paraquat by itself (0 % control) and the cultivated check (0 % control) did not control Florida pusley and this level of control was significantly lower than all the treatments except for glyphosate alone (22.5 % control) and paraquat plus s-metolachlor (22.5 % control). Paraquat, glyphosate, and s-metolachlor did not provide residual control of Florida pusley to any considerable degree.

After the last fallow treatment during the second year there were significant differences in pusley control between treatments. All the herbicides (100 % control) controlled pusley significantly better than the untreated and cultivated checks (0 % control). Small, tender pusley plants were completely controlled by all the herbicides used in the experiment. Cultivating before applying herbicides increased the efficacy of the herbicides compared to the first herbicide application, which was made to larger weeds.

Florida pusley counts - year 2

The untreated control had the highest Florida pusley counts. Pusley numbers increased in the untreated and cultivated check plots throughout the fallow season (Figure 2-38). In contrast, the number of pusley plants decreased during the fallow period in the plots that were treated with the herbicides used in this trial. There were not significant differences in Florida pusley counts between treatments at either sampling date. The differences in pusley counts were probably not significant due to the high variability between plots.

Cutleaf evening primrose control ratings - year1

Glyphosate alone (95 % control) and glyphosate or paraquat tank-mixes containing trifloxysulfuron or s-metolachlor ($\geq$ 95 % control) controlled cutleaf evening primrose the most and the level of control was significantly higher than cultivation alone (82.5 % control) (Figure 2-39). Glyphosate tank mixed with s-metolachlor (96.3 % control) or trifloxysulfuron (97.5 % control) provided greater cutleaf evening primrose control than paraquat alone (87.5 % control). All the treatments ($\geq$ 82.5 % control) controlled cutleaf evening primrose significantly better than the untreated control. Glyphosate provides excellent control of cutleaf eveningprimrose, however adding trifloxysulfuron or s-metolachlor to the spray solution increases cutleaf evening primrose control, especially when using paraquat.

Cutleaf ground cherry control ratings - year 2

Trifloxysulfuron with either glyphosate or paraquat provided consistent control of cutleaf ground cherry during the second year of fallowing (Figure 2-40). The other herbicides provided high levels of control when they were applied, but did not provide much residual control. This pattern of response from the fallow treatments is similar to other annual, broadleaf, sexually propagated weeds.

At the start of year two all the treatments plots where herbicides were applied the previous year, there was a significantly higher level of control ($\geq$ 65 % control) compared to the untreated and the cultivated checks (7.5 % control) (Figure 2-41). These results indicate that there was carryover control from the previous year of fallowing. The use of herbicides and to some degree cultivation, prevented cutleaf ground cherry plants from flowering, setting seeds, and depositing seeds into the soil seed bank.

Glyphosate alone (87.5 % control) did not control cutleaf ground cherry as well as the other herbicide and herbicide combinations ($\geq$ 95 % control) after the first fallow herbicide application. The soil was dry and plants were slightly wilted during the first fallow herbicide application of the second year. It is hypothesized that the dry conditions did not allow glyphosate to be absorbed and translocated to its maximum potential. Because of the condition described the efficacy of glyphosate was compromised. However, the addition of s-metolachlor or trifloxysulfuron had a synergistic effect that improved the effectiveness of glyphosate. All the herbicide treatments provided better control ($\geq$ 87.5 % control) of cutleaf ground cherry than the cultivated check (0 % control) and the untreated check.

After tilling all the plots after the first fallow herbicide applications, trifloxysulfuron tank-mixed with either glyphosate or paraquat (100% control) provided a higher level of control than all the other fallow weed control methods ($\leq$ 25 % control). Trifloxysulfuron provided residual control of cutleaf ground cherry, even after cultivating. This same phenomenon was realized with many other broadleaf, annual weeds, which are primarily dispersed by seeds.

After the second herbicide applications of the second year, all the herbicides (100 % control) used in this experiment for fallow weed control provided better control of cutleaf ground cherry compared to the cultivated check (0 % control) and the untreated check. Cultivating and then applying herbicides is a very effective protocol to control weeds. This procedure is commonly used in stale seedbed preparation. Cultivating stimulates a flush of seedlings and herbicides kill these tender, highly susceptible seedlings without disturbing the soil. Therefore two objectives are accomplished, the existing seedlings are killed and new seedlings do not emerge since the soil is not disturbed (such as in no-till agricultural operations).

Cutleaf ground cherry counts - year 2

The counts of cutleaf ground cherry were lower in all the treatment plots when compared to the untreated control, across all treatment dates (Figure 2-42). Cutleaf ground cherry counts were significantly higher in the untreated control after applying the first fallow applications (12 cutleaf ground cherry/m2) and after cultivating the field after these applications (52 cutleaf ground cherry/m2 compared to all the other fallow treatment plots ($\leq$ 7 cutleaf ground cherry/m2) during the same time period (Figure 2-43). There were no significant differences in cutleaf ground cherry counts in the plots after the second fallow applications were applied.

Carpetweed fallow control ratings - year 2

Trifloxysulfuron provided consistently high control of carpetweed throughout the second year of fallowing (Figure 2-44). In addition, all the herbicides provided excellent carpetweed control after they were applied. Cultivation and the untreated plots did not control carpetweed.

Trifloxysulfuron mixed with either glyphosate or paraquat (100% control) controlled carpetweed significantly better than the other treatments (0% control) after cultivation following the first fallow herbicide applications (Figure 2-45). Trifloxysulfuron provided residual control in many other weeds in the field as well.

After the second fallow applications there were significant differences in carpetweed control between treatments. Carpetweed was controlled significantly better in plots treated with herbicides (100% control) compared to the untreated and cultivated checks (0% control). Complete control of carpetweed was controlled with all herbicides after the plots were tilled; therefore there is no advantage of using any particular herbicide over another. The least expensive herbicide would be the best choice to control carpetweed and there in no need to tank-mix herbicides.

Carpetweed counts - year 2

Carpetweed counts decreased towards the end of the second year of fallowing regardless of treatment (Figure 2-46). There were not significant differences in carpetweed counts until after the second herbicide applications were applied. After the second fallow application, all the herbicide treatment plots had a significantly lower carpetweed density ($\leq$ 0.5 carpetweed/m2) than the untreated (9 carpetweed/m2) and cultivated checks (11 carpetweed/m2) (Figure 2-47). The results obtained for the various treatment counts are consistent with the control ratings that were taken. All the herbicides used in the experiment provide excellent carpetweed control and would be practically implemented in modern horticultural production.

Redweed control ratings - year 2

There were significant differences in redweed control between treatments by the end of the season. Redweed was controlled best in all the plots that were treated with herbicides (100 % control) and this level of control was significantly higher than the untreated and cultivated checks (0 % control) (Figure 2-48). The herbicides were applied to young weeds that emerged after being sprayed and tilled. At this stage of development the weeds were more effectively controlled.

Cabbage Vigor Ratings and Weed Control Ratings during the Crop

Purple nutsedge, yellow nutsedge, crabgrass, and purslane control differed significantly in the cabbage crop between fallow treatment plots. In addition, purple nutsedge, crabgrass, cutleaf evening primrose, and purslane control was significantly different between pre-plant herbicide subplots during the growing season. Lastly, cabbage vigor was significantly different between fallow treatment areas.

Purple Nutsedge

Fallow treatment effect

Glyphosate tank mixed with s-metolachlor (65.8% control) or trifloxysulfuron (78.3 % control), paraquat (72.5 % control) and paraquat tank-mixed with s-metolachlor (79 % control) or trifloxysulfuron (65 % control) that were applied during the summer controlled purple nutsedge the best initially after cabbage was planted (Figure 2-49). Paraquat plus s-metolachlor (79 % control) controlled purple nutsedge in the initial stages of the crop better than glyphosate alone (60 % control), cultivation alone (52.5 % control), and the untreated check. Glyphosate plus trifloxysulfuron (78.25 % control) and paraquat alone (72.5 % control) controlled purple nutsedge better than the cultivated (52.5 % control) and untreated checks. All the treatment methods provided significantly better nutsedge control ($\geq$ 52.5 % control) when compared to the untreated check.

On the second sampling date during the growing season, there were significant differences in purple nutsedge control between fallow treatments as well. The untreated check (18.8 % control) did not control purple nutsedge as well as the other methods of weed control ($\geq$ 71.9 % control); regardless of which pre-plant herbicide was used. The cultivated control (94.4 % control) and all the fallow herbicide treatments ($\geq$77.5 % control) except for glyphosate plus s-metolachlor (71.9 % control) provided the highest level of purple nutsedge control. Hoeing every to weeks (cultivated check) (94.4% control) during the crop provided significantly better purple nutsedge control than glyphosate plus s-metolachlor (71.9 % control).

On the last sampling date of sampling, all the herbicide fallow treatments ($\geq$ 68 % control) and hand hoeing (85.6 % control) during the growing season provided the highest level of purple nutsedge control, this was significantly better than the untreated control (18.8 % control).

In summary, applying herbicides during the fallow period provided control of purple nutsedge that carried over into the cropping season. All of the fallow herbicides provided similarly high purple nutsedge control in the crop. Initially hand hoeing (cultivation) did not control purple nutsedge as well as the fallow herbicides. However, after hand hoeing routinely every other week cultivation provided excellent purple nutsedge control. Multiple consecutive fallow herbicide applications made over two contiguous years of both systemic and burndown post emergent materials tank-mixed with pre-emergence herbicides did not cause drastically different nutsedge control during the crop, although there were major differences during the summer when they were applied. Tradition knowledge of both herbicides and nutsedge extensive underground growth would lead one to expect that burndown herbicides would not control purple nutsedge to the same degree as systemic herbicides. Although this may true for a single herbicide application, multiple herbicide applications coupled with multiple tillage events compound each other and provide good control of purple nutsedge even when burndown materials are used. This is because paraquat destroyed the above ground shoots and even killed the shoot meristem when it was applied to small purple nutsedge plants because greater canopy penetration was achieved. Fallow cultivation broke up nutsedge tuber dormancy by breaking apical dominance thus allowing the tubers to sprout then the shoots to be destroyed with herbicides.   In addition, routine cultivation alone implemented at short intervals (14 days) during the crop provided excellent purple nutsedge control because it disrupted the growth of existing shoots, depleted reserves in the tubers and thus did not allow purple nutsedge to re-establish.

Pre-plant treatment effect

In reference to the efficacy of pre-plant herbicides in conjunction with fallow weed control methods on purple nutsedge, s-metolachlor (> 80 % control) provided significantly better control than oxyfluorfen (> 68 % control) (Figure 2-50). S-metolachlor is known to suppress purple nutsedge but not provide adequate control when used by itself. However, if used as pre-plant herbicide in conjunction with fallow herbicides it can provide beneficial effects that contribute to the overall level of purple nutsedge control. When s-metolachlor is used following fallow weed control methods good control of purple nutsedge is achieved.

Yellow Nutsedge Control in Cabbage

There were significant differences in yellow nutsedge control between treatment methods. All the methods used to control weeds during the fallow period (≥ 52.5 % control) controlled yellow nutsedge better than the untreated check during the crop (Figure 2-51). In addition, all the herbicide treatments (≥ 80 % control) controlled yellow nutsedge better than the cultivated check (52.5 % control). All the herbicide treatments (≥ 85 % control) except for glyphosate alone (80 % control) provided the best yellow nutsedge control. S-metolachlor tank-mixed with either paraquat or glyphosate (> 98 % control) controlled yellow nutsedge significantly better than glyphosate by itself (80 % control). S-metolachlor is extremely effective at controlling yellow nutsedge. Fallow herbicide applications can provide excellent control of yellow nutsedge in the subsequent crop. The reason that glyphosate alone did not perform to the same standards at controlling yellow nutsedge is unclear. It may be possible that applying glyphosate to small sized yellow nutsedge plants not optimal because the weeds do not absorb enough of the herbicide to kill the underground tubers.

Crabgrass Control in Cabbage

Fallow treatment effect

All the fallow treatment systems (> 83 % control) controlled crabgrass significantly better than the untreated check (58.8 % control) during the first sampling date during the crop, independent of which pre-plant herbicide was applied (Figure 2-52). Glyphosate alone (90.6 % control), S-metolachlor tank-mixed with glyphosate or paraquat (> 90% control), and cultivation (100 % control) controlled crabgrass the best. Hand-hoeing on a biweekly basis (100% control) controlled crabgrass significantly better than paraquat alone (83.8 % control) and trifloxysulfuron mixed with either glyphosate (86.3 % control) or paraquat (87.5 % control).

There were also differences in crabgrass control between fallow treatments, on the second sampling date. All treatments (> 70 % control) controlled crabgrass significantly better than the untreated check (40 % control). Cultivation (98 % control) controlled crabgrass better than paraquat plus trifloxysulfuron (70.6 % control). All the other herbicides ($\geq$ 78.8 % control) were equally as effective as hand hoeing (98 % control) at controlling crabgrass.

Cultivation had an immediate positive effect at controlling crabgrass. Scheduling frequent hand hoeing during the crop will effective control the existing crabgrass population and prevent future infestations from taking grasp. Trifloxysulfuron did not control crabgrass in the fallow period; therefore it was not expected to control crabgrass during the cropping season. The addition of trifloxysulfuron to glyphosate or paraquat decreased the control of those herbicides in most cases; however the decrease in control was not significant. It is unclear if the addition of trifloxysulfuron yields an antagonistic response on crabgrass control when applied with other herbicides. However, the addition of trifloxysulfuron is definitely not beneficial to control crabgrass. In contrast, the addition of s-metolachlor in the fallow period did increase crabgrass control but not significantly.

Pre-plant treatment effect

There were also significant differences in crabgrass control between pre-plant herbicide treatments. On both sampling dates oxyfluorfen (> 90 % control) provided higher control of crabgrass than s-metolachlor (> 65 % control) (Figure 2-53). Oxyfluorfen would be preferred to s-metolachlor to control crabgrass in cabbage. Although, s-metolachlor is more effective at controlling purple nutsedge, it did not control most other weeds (most annual weeds) as well as oxyfluorfen. According to personal communication with Dr. Stall, this is unusual. S-metolachlor usually provides better control of grasses compared to oxyfluorfen.

Cutleaf Evening Primrose

Fallow treatment effect

There were significant differences in cutleaf evening primrose control between pre-plant herbicides, but not between fallow treatments. Since cutleaf evening primrose is a winter annual it was not present and/or prevalent during the fallow period. Therefore, it is not practical to target this weed during the summer fallow season, but instead it is more efficient to focus control efforts during the cool season (cropping season).

Pre-plant treatment effect

Oxyfluorfen (96.6 % control) controlled cutleaf evening primrose significantly better than s-metolachlor (75.5 % control) (Figure 2-54). As seen with other types of weeds oxyfluorfen was more effective at control most annual species than s-metolachlor. Since excellent cutleaf evening primrose is achieved with oxyfluorfen as a pre-plant herbicide, there is no need to apply fallow herbicides or cultivate during the fallow period to control this particular weed.

Purslane Control in Cabbage

Fallow treatment effect

Cultivation (100 % control) and the untreated check (82.5 % control) provided the best purslane control in cabbage during the first sampling date (Figure 2-55). Hand hoeing (100 % control) every other week controlled purslane significantly better than all the chemical fallow methods ($\leq$ 70 % control). The untreated check (82.5 % control) provided better control of purslane than glyphosate alone (60 % control) and paraquat plus s-metolachlor (61.3 % control).

The methods that provided the best purslane control on the second sampling dates were the untreated check (87.5 % control), glyphosate alone (86.25 % control), glyphosate tank-mixed with trifloxysulfuron (81.3 % control), and the cultivated check (99.4 % control). Cultivation (99.4 % control) provided significantly higher control of purslane than all the treatments containing paraquat ($\leq$ 71.3 % control) and glyphosate plus s-metolachlor (74.4 % control). Even the untreated check (87.5 % control) provided significantly better purslane control than paraquat plus trifloxysulfuron (68.1 % control). It is unusual for the untreated check to control a weed better than the treated plots. However, it is possible that the competition from other weeds such as purple nutsedge was too intense for purslane to become established. In the treated plots competition with purslane from other weeds was much less and thus purslane was allowed to grow freely. Since purslane is an annual weed that is propagated by seed, the fallow treatments did not provide control from the fallow period after the field was cultivated and prepared for planting.

Pre-plant treatment effect

Purslane was controlled to a higher degree by the pre-plant herbicide oxyfluorfen (> 98 % control) rather than s-metolachlor (< 61 % control) on both sampling dates (Figure 2-56). Oxyfluorfen was excellent at controlling purslane and should be recommended for pre-plant control in cabbage. Fallow weed control methods are most likely not necessary to control purslane in vegetables, unless there are no effective pre-plant herbicides labeled for a specific crop.

Cabbage Weed Counts

Fallow treatment effect: There were significant differences in purple nutsedge counts in cabbage between the fallow treatment plots. In addition, there were differences in yellow nutsedge and crabgrass counts between pre-plant herbicide treatments.

Purple nutsedge counts were significantly higher in the untreated treatments (217 purple nutsedge/m2) compared to all the other fallow treatments (< 49 purple nutsedge/m2) (Figure 2-57). The counts in the other fallow treatments were similar during the cropping season (15 – 49 purple nutsedge/m2). These findings are similar to the purple nutsedge rating results, but not exactly the same. As noted earlier, control ratings may differ slightly than counts. All living nutsedge in any condition was tallied in the counts. However, the ratings took into account the condition the plants were in when they were observed.

Yellow nutsedge counts were significantly higher in the oxyfluorfen (0.9 yellow nutsedge/m2) treated plots compared to plots treated with s-metolachlor (0 yellow nutsedge/m2) (Figure 2-58). These results are consistent with the results found with the purple nutsedge ratings. S-metolachlor provided better control of both purple and yellow nutsedges than oxyfluorfen.

Crabgrass numbers were significantly higher in the plots treated with s-metolachlor (4.6 crabgrass/m2) than oxyfluorfen (0.9 crabgrass/m2) (Figure 2-59). Oxyfluorfen controlled most annual weeds better than s-metolachlor, but not perennial nutsedge. The results for crabgrass counts response to these pre-plant herbicides are consistent with the findings from the crabgrass control ratings. Applying oxyfluorfen before planting cabbage is highly recommended to control crabgrass even if the field was treated during the fallow period.

Cabbage Vigor

Fallow treatment effect : Cabbage vigor differed significantly between fallow treatments but not between pre-plant herbicides. The cabbage in the untreated plots (76 % vigor) were the least vigorous, but this was not significantly lower than the cabbage vigor in the glyphosate plus trifloxysulfuron (83 % vigor) and cultivation plots (79 % vigor) (Figure 2-60). The herbicide treatments provided the most vigorous cabbage ($\geq$ 85.9 % vigor) except for glyphosate tank-mixed with trifloxysulfuron (83 % vigor). The cabbage in the paraquat plus s-metolachlor (88.8 % vigor) plots were significantly more vigorous than the cabbage in the glyphosate plus trifloxysulfuron (83 % vigor) and cultivation plots (79 % vigor). In summary, vigor was less in the untreated plots, cultivated plots, and trifloxysulfuron treated plots. Cabbage vigor was less in the untreated plots because there was an overwhelming amount of weeds present that negatively impacted cabbage growth. The vigor was probably less in the cultivated plots because the cabbage roots were disturbed slightly by frequent hoeing. It seems trifloxysulfuron may have a negative impact on cabbage growth and development even when it is applied during the summer.

Cabbage Yield - Year 2

Cabbage number, total weight and average weight differed significantly between fallow treatment plots. The total yield and the average weight per head of cabbage were significantly different between pre-plant herbicide treatments.

Cabbage Number

Fallow treatment effect: The treatment plots with the highest number of cabbage were glyphosate by itself (12.6 cabbage/15 LBF), glyphosate tank-mixed with trifloxysulfuron (12.1 cabbage/15 LBF), and all of the paraquat treatments ($\geq$ 12.9 cabbage/15 LBF) (Figure 2-61). The untreated check (10.25 cabbage/15 LBF), glyphosate plus s-metolachlor (10.6 cabbage/15 LBF), glyphosate tank-mixed with trifloxysulfuron (12.1 cabbage/15 LBF), and cultivation (10.9 cabbage/15 LBF) resulted in the lowest cabbage counts per plot. Paraquat plus trifloxysulfuron (13.1 cabbage/15 LBF) resulted in a higher number of surviving cabbage at harvest than the untreated check (10.25 cabbage/15 LBF), glyphosate plus s-metolachlor (10.6 cabbage/15 LBF), and biweekly cultivation (10.9 cabbage/15 LBF). All the treatments containing paraquat ($\geq$ 12.9 cabbage/15 LBF) had higher cabbage numbers than the untreated check (10.25 cabbage/15 LBF) and glyphosate plus s-metolachlor (10.6 cabbage/15 LBF). All the herbicide treatments except the glyphosate tank-mixes (10.6 to 12.1 cabbage/15 LBF) contained a greater number of cabbages than the untreated check (10.25 cabbage/15 LBF).

Cabbage survival was low in the untreated plots because of excessive unmanaged weed competition for resources such as sunlight, water, and nutrients. Allelopathic chemicals produced by the weeds may have also been a factor that resulted in the decline of stand establishment. Frequent cultivation could have disturbed cabbage roots which had a direct effect on water and nutrient uptake. In addition, cultivation may have slightly injured cabbage roots which led to increased susceptibility to soil borne pathogens that indirectly led to decreased water and nutrient uptake. An explanation for the decreased establishment in the plots treated with glyphosate plus s-metolachlor in the fallow period is uncertain.

External factors such as fertilizer toxicity and lateral herbicide movement may have led to the decline in cabbage numbers. Fertilizer was applied by hand which was not the most accurate and uniform method of distribution. On one occasion when the fertilizer was applied the soil was moist which made the fertilizer dissolve however irrigation was not provided to dilute the granular fertilizer until several days later therefore the fertilizer was more too concentrated. The pre-plant herbicide labels warn against stressing the transplants by drought or over fertilization to avoid herbicide toxicity and possible death. In addition, the field had a slight slope which would cause overhead irrigation water to pool more on one side of the field. This side of the field had less vigorous cabbage, however it is unclear whether the plants suffered from over irrigation or chemicals dissolved in the irrigation water which accumulated there in greater amounts.

Total Cabbage Weight

Fallow treatment effect: The total cabbage weight was highest in the plots treated with glyphosate (47 lbs/15 LBF), glyphosate plus s-metolachlor (41 lbs/ 15 LBF), and all the paraquat treatments ($\geq$ 43 lbs/15 LBF) (Figure 2-62). The total weight was significantly higher in all the paraquat treatments ($\geq$ 43 lbs/ 15 LBF), and glyphosate alone (47 lbs/15 LBF) when compared to the untreated (30 lbs/15 LBF) and cultivated checks (33 lbs/15 LBF). In addition, glyphosate alone (47 lbs / 15 LBF) and paraquat tank-mixed with s-metolachlor (50 lbs/ 15 LBF) resulted in higher total cabbage yields than glyphosate plus trifloxysulfuron (37 lbs/ 15 LBF).

It is not known why trifloxysulfuron reduced cabbage yield when added to glyphosate but not paraquat. External factors may be involved. Additional studies should be conducted to verify these results. However, most of the herbicides used during the fallow period increased the yield of cabbage compared to the untreated control, which was the one of the main goals of this experiment.

In addition, all of the paraquat treatments and glyphosate alone increased cabbage total yield compared to the cultivated check. This indicates that two herbicide applications during the summer results in a higher yield level than frequent season long tillage. Herbicides do not disturb the soil and the crop roots which may have lead to the increase in total yields. Pre-plant herbicide application and planting was done on the same day for all the plots. However, cultivation did not begin until two weeks after planting, which may have allowed early weed competition to occur and ultimately result in lower cabbage yields. Meanwhile, the plots treated with herbicides during the fallow period had the lowest weed infestation at planting.

Average Cabbage Weight

Fallow treatment effect: Cabbage average weight was highest in the plots treated with glyphosate (3.8 lbs/head), glyphosate plus s-metolachlor (4 lbs/head), paraquat plus s-metolachlor (3.9 lbs/head) and paraquat alone (3.5 lbs/head) (Figure 2-63). The treatments that resulted in the lowest cabbage average weights were the untreated check (3 lbs/head), glyphosate plus trifloxysulfuron (3 lbs/head), paraquat plus trifloxysulfuron (3.3 lbs/head), paraquat alone (3.5 lbs/head) and the cultivated check (3 lbs/head). Average cabbage weights were higher in the glyphosate plus s-metolachlor treated plots compared to the plots treated with glyphosate plus trifloxysulfuron, paraquat tank-mixed with trifloxysulfuron, the cultivated check and the untreated check. In addition, glyphosate alone and paraquat plus s-metolachlor yielded larger cabbages than the untreated check, glyphosate plus trifloxysulfuron, and the cultivated check.

S-metolachlor used during the fallow increased the weight of the average cabbage when added to either paraquat or glyphosate, although not significantly. Since paraquat and glyphosate only control emerged weeds the addition of pre-plant herbicide applied in the fallow season increases the overall level and spectrum of weed control. When added to glyphosate or paraquat, trifloxysulfuron also increased the overall level and spectrum of weed control, however trifloxysulfuron may also cause slight stunting which is why the vigor and average cabbage weight is slightly lower, however not significantly. In contrast, trifloxysulfuron did not adversely affect the number of cabbage produced, which means the herbicide toxicity did not result in cabbage death but possibly stunting.

Total Cabbage Weight

Pre-plant treatment effect: Overall, cabbage yields were significantly higher in the oxyfluorfen (44 lbs/15 LBF) treated plots compared to the ones treated with s-metolachlor (38 lbs/15 LBF), when averaged across all fallow treatment plots (Figure 2-64). Broadleaf and grass weeds are commonly more competitive with crops than sedges at low infestation numbers. In general, oxyfluorfen provided superior control of broadleaf and grass weeds during the crop compared to s-metolachlor. Fallow weed control methods should be implemented to control various weeds, especially purple nutsedge. Pre-plant herbicides should be used to treat the remaining weeds that escape fallow control and pose an infestation threat to the crop.

Average Cabbage Weight

Pre-plant treatment effect: The average weight per cabbage was significantly higher in oxyfluorfen (3.8 lbs/head) treated plots than s-metolachlor (3.1 lbs/head) (Figure 2-65). Similarly to total yield the oxyfluorfen treated plots resulted in bigger cabbages. Oxyfluorfen controlled broadleaf and grass weeds better than s-metolachlor, therefore the cabbages were allowed to grow with less competition which yielded bigger plants. Although oxyfluorfen did not control purple nutsedge as well as s-metolachlor, the fallow treatments primarily controlled purple nutsedge whereas the pre-plant herbicides primarily controlled sexually propagated weeds that emerged following the disturbance caused by field preparation.

Weeds after Cabbage Harvest

Purple nutsedge post cabbage harvest

After the cabbage was harvested and all the plots were cultivated, there were significant differences in weed control between treatments. All the herbicides ($\geq$ 70.6 % control) except glyphosate tank-mixed with s-metolachlor (55 % control) provided the best purple nutsedge control (Figure 2-66). These herbicides ($\geq$ 70.6 % control) controlled purple nutsedge significantly better than glyphosate plus s-metolachlor (55 % control) and the untreated check (15.6 % control). Trifloxysulfuron tank mixed with either glyphosate or paraquat (80 % control) and paraquat plus s-metolachlor (81 % control) gave significantly higher purple nutsedge control than cultivation alone (62.5 % control). All the treatments ($\geq$ 55 % control) provided significantly better nutsedge control compared to the untreated check.

The effects of fallow weed control treatments are beneficial during the fallow, the crop and even after the fall crop into the spring crop. Applying herbicides during the summer fallow season decreased purple nutsedge more than biweekly hand hoeing implemented throughout the fall cropping season. Hand hoeing has a short term effect on nutsedge control. Cultivation controls nutsedge shortly after it is performed however, once cultivation has ceased nutsedge is able to re-establish itself and begin to proliferate. A speculative reason to explain why s-metolachlor (mixed with glyphosate) increased purple nutsedge control during the fallow period, during the beginning of the cropping season but not toward the end of the crop and after the crop is that s-metolachlor only provides temporary purple nutsedge control. S-metolachlor might hinder root and shoot growth from viable tubers but not kill the tuber completely. If s-metolachlor delays shoot emergence until after glyphosate is applied then glyphosate will not be absorbed, translocated within the plant, and control the underground tubers.

Crabgrass post cabbage harvest

There were significant differences in crabgrass control between treatments following the cabbage harvest. All the herbicides (> 66 % control) used in this study controlled crabgrass better than hand-hoeing (33 % control) and the untreated check after the crop (Figure 2-67). In addition, the cultivated check (33 % control) provided higher crabgrass control than the untreated check but not as much as the different herbicides (> 66 % control).

Although cultivation provided excellent crabgrass control during the crop, it did not provide long term crabgrass control. In contrast, the herbicides used provided long term control of crabgrass. The fallow herbicides controlled the crabgrass plants and germination seedlings during the summer. In addition, the herbicides prevented crabgrass from producing seeds and depositing them into the soil profile. Although cultivation during the crop did prevent the plants present from producing seeds, the main growth season of crabgrass is in the warmer temperatures of the late spring, summer, and early fall. Once temperatures become low, seeds become dormant and do not germinate. Therefore, summer fallow treatments targeted the optimal crabgrass growing season when seeds are produced. Cultivation during the summer does result in a flush of crabgrass, which can then be killed by herbicides or subsequent tillage. However, fully mature crabgrass plants are totally controlled during summer cultivation, because the soil is moist and plant fragments become propagative material.

Pusley post cabbage harvest

Florida Pusley was controlled best by cultivating (88 % control) during the growing season and by all the fallow applied herbicides (> 70 % control) except for paraquat alone (51 % control) after the cabbage had been harvested (Figure 2-68). All the treatments (> 51 % control) controlled pusley to a greater extent than the untreated check. Glyphosate alone (80 % control), paraquat tank mixed with trifloxysulfuron (84 % control), and cultivation (88 % control) controlled pusley significantly better than paraquat alone (51 % control).

Implementation of all the proactive fallow treatments resulted in dramatically increased Florida Pusley control compared to leaving the field unattended. Cultivating, glyphosate, and all the tank mixes with pre-plant herbicides provided excellent long term control of Florida Pusley by destroying the plants, therefore preventing them from producing viable seeds. However, paraquat is a contact herbicide that did not kill the shoot meristem of pusley, thus it was able to re-grow and produce seeds after being treated.

Purslane post cabbage harvest

All the treatments ($\geq$ 27.5 % control) except paraquat plus s-metolachlor (17.5 % control) controlled purslane significantly better than the untreated check (Figure 2-69). The cultivated check (27.5 % control) and all the herbicides ($\geq$ 33.75 % control) except paraquat plus s-metolachlor (17.5 % control) provided the highest degree of purslane control following in the fallow period after cabbage harvest. Glyphosate plus s-metolachlor (52.5 % control) and paraquat alone (44 % control) controlled purslane significantly better than paraquat plus s-metolachlor (17.5 % control).

Most of the fallow treatments had a positive impact on carryover purslane control after cabbage was harvested. However, an explanation for the decreased control response obtained in the paraquat plus s-metolachlor in not clear. Perhaps this should be further investigated to determine if this response is reproducible and provide clarity on the matter.

Conclusions

Fallow Treatments

Untreated fallow

The untreated fallow treatment did not control any weeds. The weeds were left unmanaged and allowed to grow unchecked. Weeds in the untreated fallow proliferated via seeds and vegetative parts. Leaving the field unattended during the fallow period allowed the weeds to become more numerous and negatively impacted subsequent crop growth, development, and yield through increased competition for vital resources.

Cultivation

Cultivation controlled the weeds better than the untreated check, when cultivation was performed. However, cultivation had no pre-emergent or residual weed control. Weed infestation levels quickly reached their original levels when the land was left undisturbed. In many cases tillage increased weed counts of pioneer species, which are the first to colonize disturbed areas, because competition from other weeds was removed. Cultivation does prevent plants from forming seeds and depletes the soil seed bank reserves. Tillage plays a crucial role in inducing seeds to germinate and provides a prime opportunity for targeting seedlings with herbicides. Seedlings are most susceptible growth stage and are most effectively controlled with herbicides since they are young, tender, and feeble. Cultivation controlled purple nutsedge compared to the untreated check. Frequent cultivation under dry soil conditions, depleted carbohydrate reserves in the tuber and caused the tubers to desiccate rather than reestablishing themselves. Hand-hoeing biweekly during the crop provided excellent temporary control of all weeds, however cabbage vigor, stand establishment, plant size, and total yield suffered compared to the best fallow herbicide treatments. Cultivation disturbs the soil, which may have damaged cabbage roots, therefore hindering crop growth. Using pre-plant herbicides during the crop resulted in similar yields in the cultivated and untreated plots fallow plots.

Glyphosate

Fallow applications of glyphosate provided post emergent control of all of the weeds present when it was applied. The full impact of glyphosate on the plant was not immediate. A few weeks were needed to realize the full extent of glyphosate control. Glyphosate did not provide any pre-emergent or residual weed activity. This herbicide provided temporary and long term control of purple and yellow nutsedge because it killed the underground tubers of the plant. Multiple applications were needed to control purple nutsedge. In addition, the efficacy of glyphosate was dependent on weed species and environmental conditions. Glyphosate lowered the amount of seed rain produced by sexually reproducing plants which had a direct impact on the soil seed bank. The populations of subsequent weed populations were lowered compared to the untreated check due to the lowered weed pressure. Applications made to weeds during drought stress conditions reduced the efficacy of glyphosate considerably. Glyphosate provided long term control of weeds during the crop after the fallow period and even after the crop was removed the effects could still be clearly observed. Although fallow applications of glyphosate is effective at controlling nutsedges during the cropping season, a pre-plant herbicide should be used during the crop to provide enhanced control of broadleaf and grass weeds. Lastly, fallow glyphosate applications resulted in increased crop yields compared to the untreated check, and did not cause herbicide toxicity in cabbage.

Glyphosate plus s-metolachlor

Applying a mixture of glyphosate and s-metolachlor provided a synergistic effect on weed control in most species. In addition, to the post emergent control provided by glyphosate, s-metolachlor gave beneficial pre-emergent control of many weeds including sedges, broadleaves, and grasses. Residual weed control was not provided by s-metolachlor. S-metolachlor tank-mixed with glyphosate did not hinder crop growth and yields. Although this combination controlled many weeds during the fallow season, pre-plant herbicides should be used to increase weed control during the crop.

Glyphosate plus trifloxysulfuron

Glyphosate tank mixed with trifloxysulfuron provided excellent broad spectrum weed control during the fallow period. Trifloxysulfuron mixed with glyphosate provided post emergent, pre-emergent, and residual control of sedge and broadleaf weeds. Post emergent control of grasses was provided by this herbicide mixture. The residual control of sedges and broadleaf could be observed by the high level of weed suppression following tillage events. The glyphosate alone and glyphosate tank mixed with s-metolachlor did not continue to provide effective control of weeds, especially annual broadleaf weeds after cultivation. Trifloxysulfuron plus glyphosate permanently stunted nutsedge plants after treatments were applied. In addition, trifloxysulfuron mixed with paraquat revealed similar residual control properties. These results indicate that trifloxysulfuron provided the residual control in these mixtures and is an important compound for providing residual control of sedge and broadleaf weeds during the fallow season.

Vigor or yield differences between treatments were not observed in the corn crop planted after the first year of fallowing. Unfortunately, fallow applications of glyphosate plus trifloxysulfuron may have slightly decreased cabbage vigor, size, and total yield compared to the most promising fallow herbicide treatments but not compared to the untreated or cultivated check. Corn is less sensitive to trifloxysulfuron toxicity than cabbage. In addition, the corn was planted in spring following the fallow treatments, while the cabbage was planted in the fall directly after the summer fallow. In the corn crop, the longer layover period may have allowed the herbicide to degraded and nullify the toxic effects observed in cabbage. Lastly, corn is a grass crop and trifloxysulfuron does not provide residual control of grass weeds, which would explain the response of corn to this particular herbicide.

Paraquat

Typically contact herbicides like paraquat do not control weeds as well as systemic herbicides like glyphosate and trifloxysulfuron. Paraquat is not absorbed into the plant and translocated to the actively growing portions of the plant. Thus, it is unable to effectively control underground structures such as tubers, and meristems that are covered by plant canopies, which is typical with older grasses, sedges, and broadleaves. However, in the current experiment, consisting of multiple sequential paraquat applications with tillage implemented between herbicide applications, paraquat was able provide post emergent control of nutsedges, broadleaves, and grasses. Initial applications of paraquat burned down large weeds that were present at the beginning of the fallow season, however many were not killed. Many weeds were able to re-sprout from tubers, and shielded above ground shoot meristem. However, this application depleted the weeds of carbohydrate reserves and prevented them from developing seeds or producing new underground propagative structures, such as tubers. Tillage destroyed most of the existing broadleaf, and grass weeds, especially since they were already in a weaken state. Tillage also destroyed nutsedge shoots, causing them to re-sprout from tubers. The second application of paraquat was able to kill most of the weeds because unlike before they were small, tender, exposed, and vulnerable to control with paraquat. During the second application paraquat was able to destroy weeds including purple nutsedge and grasses, because the exposed shoot meristem of the small plants were penetrated by the spray due to the lack of canopy cover. Continuing with two spray applications, two cultivation events for two consecutive years enabled successful weed control for almost all species by continually depleting carbohydrate reserves, preventing seed rain, depleting the soil seed bank, and killing small plants. Paraquat did not provide any pre-emergent or residual control of weeds.

No yield differences in yield or vigor between fallow treatments were noticed in corn. Applying paraquat during the summer fallow in conjunction with pre-plant herbicides during the cropping season provided the highest level of cabbage vigor, stand establishment, size, and yield. Cabbage is less competitive than corn; therefore weed infestations have a more pronounced negative effect on cabbage yield.

Paraquat plus s-metolachlor

The addition of s-metolachlor to paraquat provided pre-emergent weed control activity which does not occur with paraquat alone. Therefore, these herbicides were complimentary to each other because they provided weed control to existing plants and emerging seedlings, which broadened the spectrum of weed control possibilities that either herbicide could not provide alone. However, this herbicide combination did not provide any long term residual weed control.

Paraquat plus s-metolachlor resulted in the highest level of vigor, stand establishment, fruit size, and yield in cabbage and corn.

Paraquat plus trifloxysulfuron

Trifloxysulfuron mixed with paraquat gave excellent post emergent control of sedges, grasses, and broadleaves when applied. Pre-emergent and residual control of broadleaves and sedges were achieved using paraquat plus trifloxysulfuron. However, these herbicides did not provide pre-emergent or residual control of grasses.

Cabbage vigor, stand establishment, and total yield were very high when using these herbicides during the fallow period. However, cabbage size may have suffered slightly.

Pre-plant Herbicide Treatments

Oxyfluorfen

Oxyfluorfen provided better weed control of broadleaf and grass species. In addition, the use of oxyfluorfen resulted in greater cabbage yields. Oxyfluorfen did not control nutsedges as well as s-metolachlor, however, nutsedge control was mainly a factor of fallow herbicide treatments rather than pre-plant herbicide treatments.

S-metolachlor

As a pre-plant herbicide treatment s-metolachlor controlled nutsedges better than oxyfluorfen. However, s-metolachlor did not control broadleaf and grass weeds well compared to oxyfluorfen. S-metolachlor resulted in lower cabbage yields than oxyfluorfen. Pre-emergent herbicides used in conjunction with fallow herbicide treatments need to control annual grass and broadleaf weeds rather than nutsedges since long term control of nutsedge is provided primarily by fallow herbicide treatments.

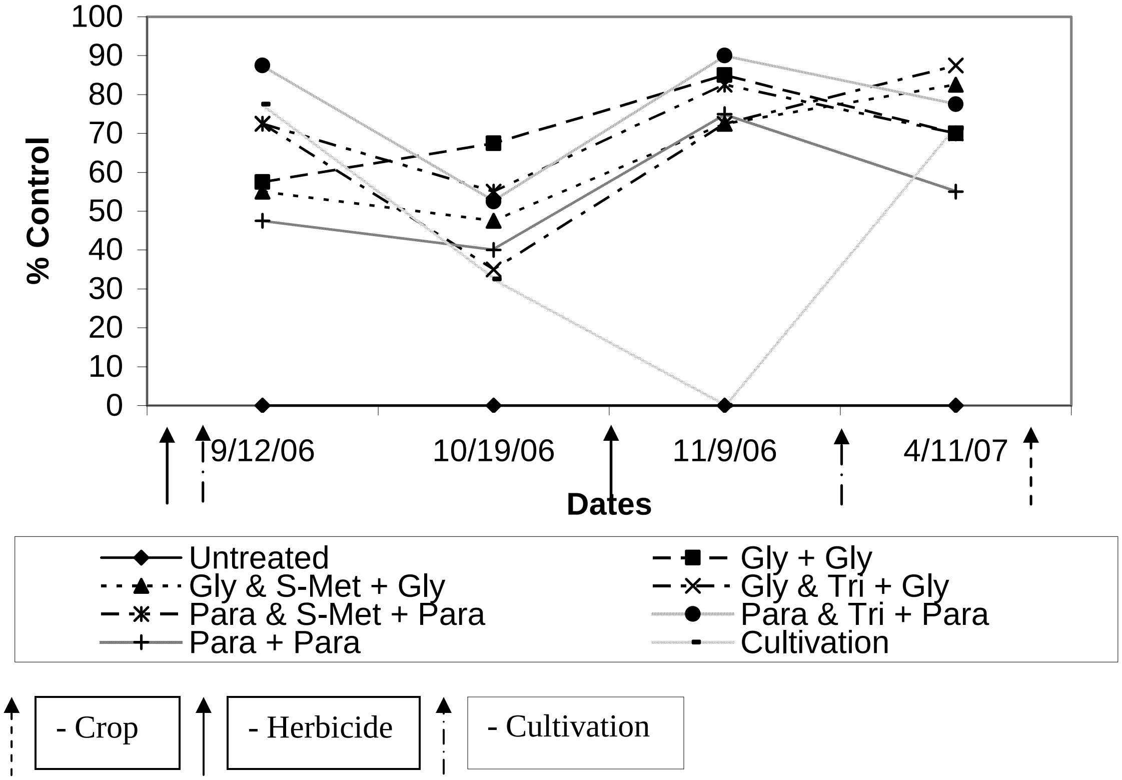


Figure 2-1. Effect of different fallow treatments on the control of purple nutsedge during the first fallow season in Citra, Fl. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was only performed in the cultivation treatment plots during the fallow period and no cultivation was implemented during the growing season. Note x axis dates and treatment applications timelines are not drawn to scale.

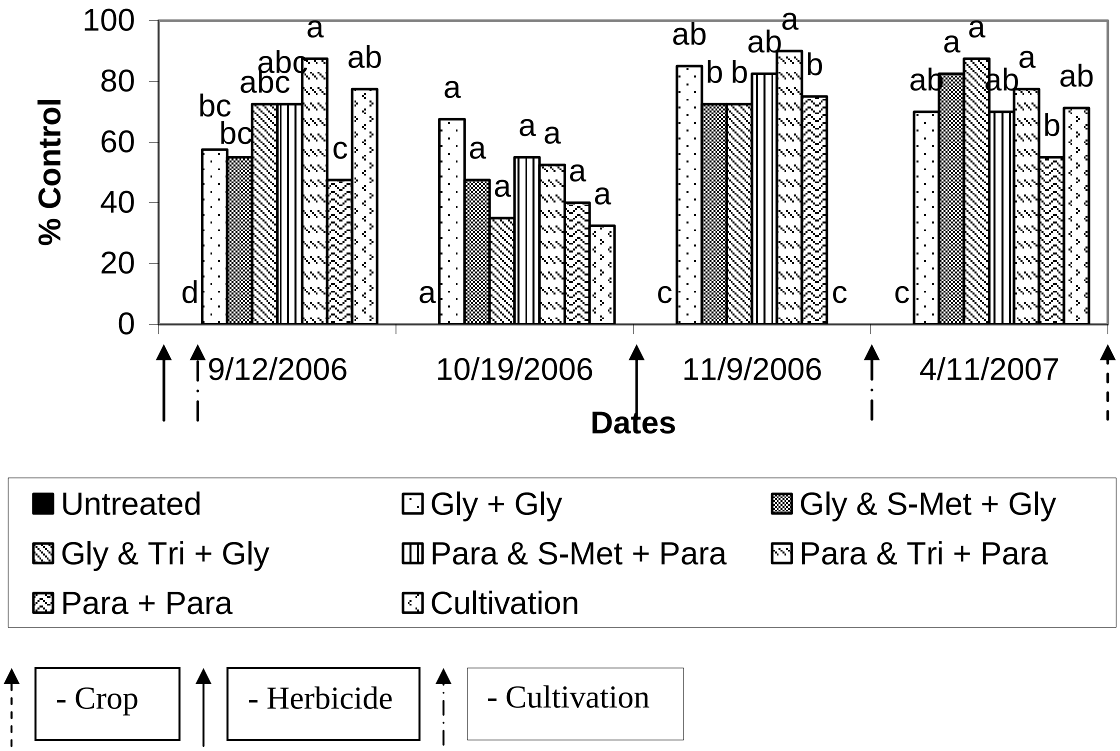


Figure 2-2. Effect of different fallow treatments on the control of purple nutsedge during the first fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was only performed in the cultivation treatment plots during the fallow period and no cultivation was implemented during the growing season. Note x axis dates and treatment applications timelines are not drawn to scale.

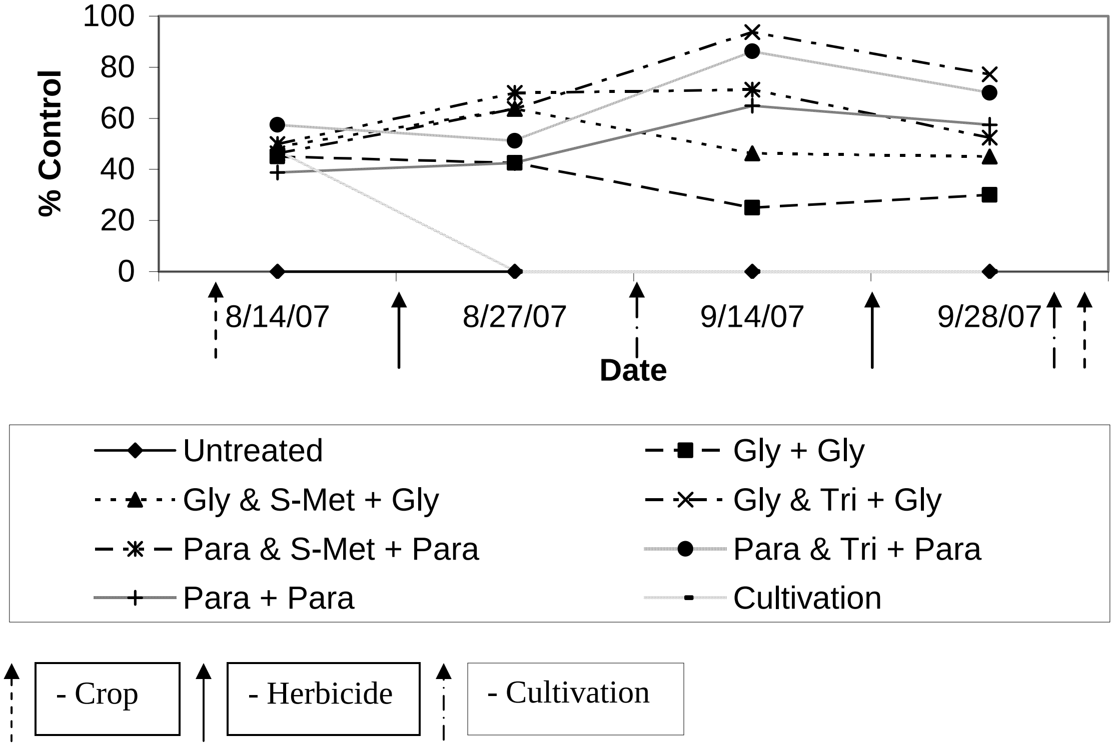


Figure 2-3. Effect of different fallow treatments on the control of purple nutsedge during the second fallow season in Citra, Fl. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

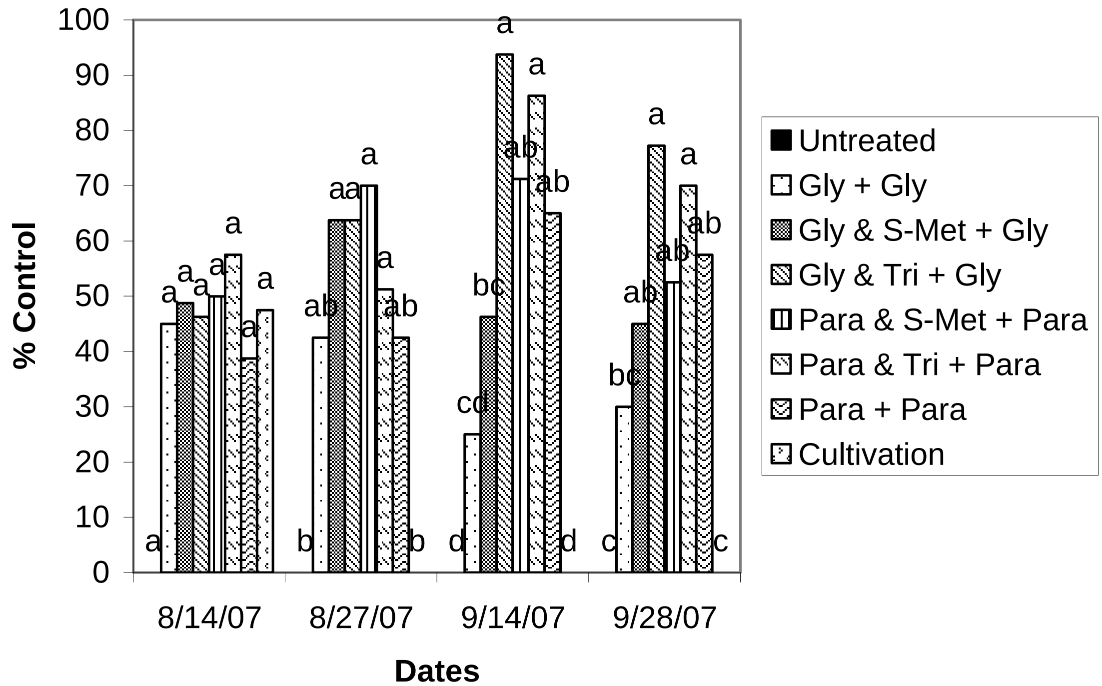


Figure 2-4. Effect of different fallow treatments on the control of purple nutsedge during the second fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop.

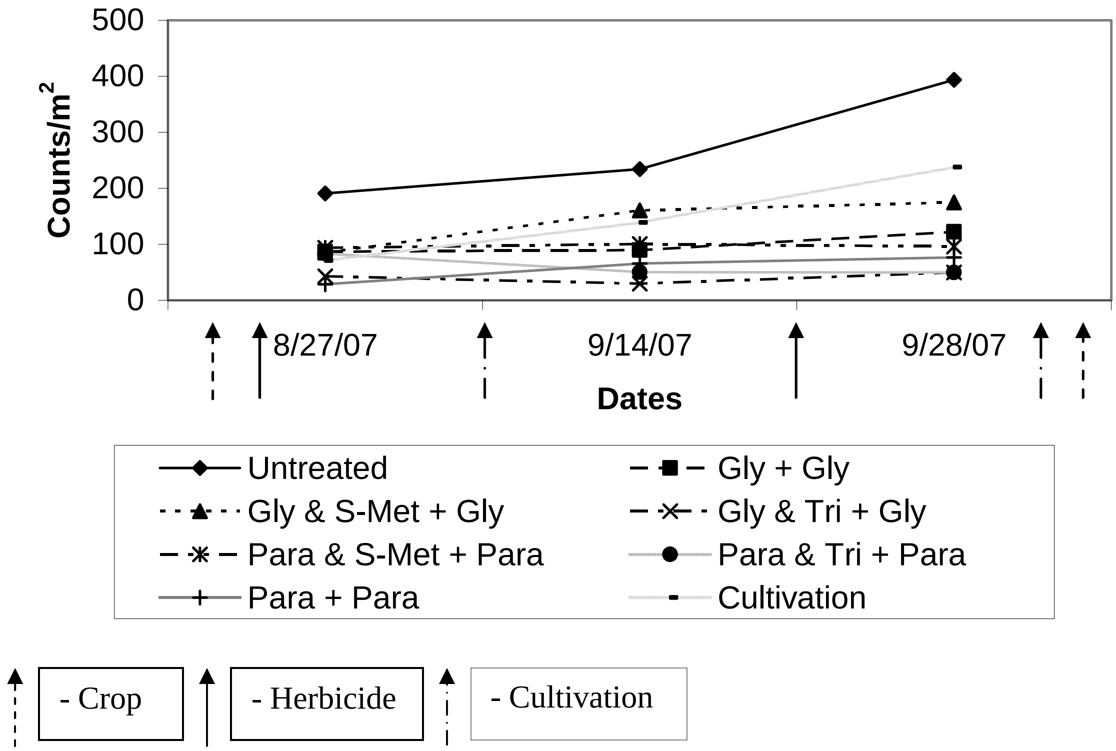


Figure 2-5. Effect of different fallow treatments on the population density of purple nutsedge during the second fallow season in Citra, Fl. Weed counts include all living plants independent of visual health. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

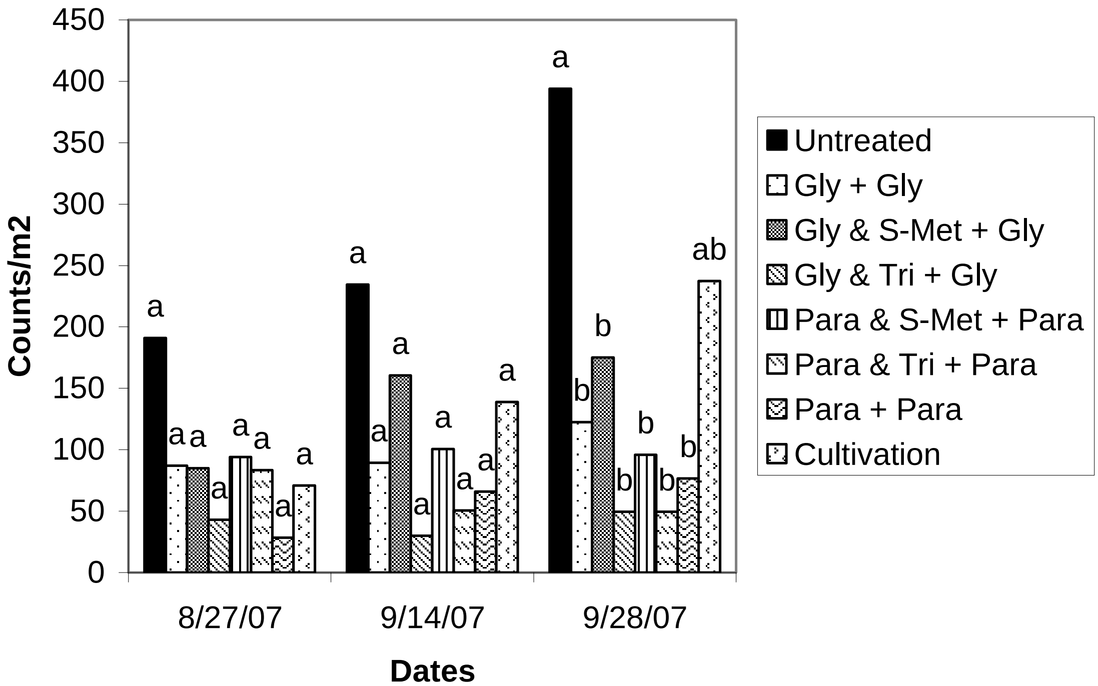


Figure 2-6. Effect of different fallow treatments on the population density of purple nutsedge during the second fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop.

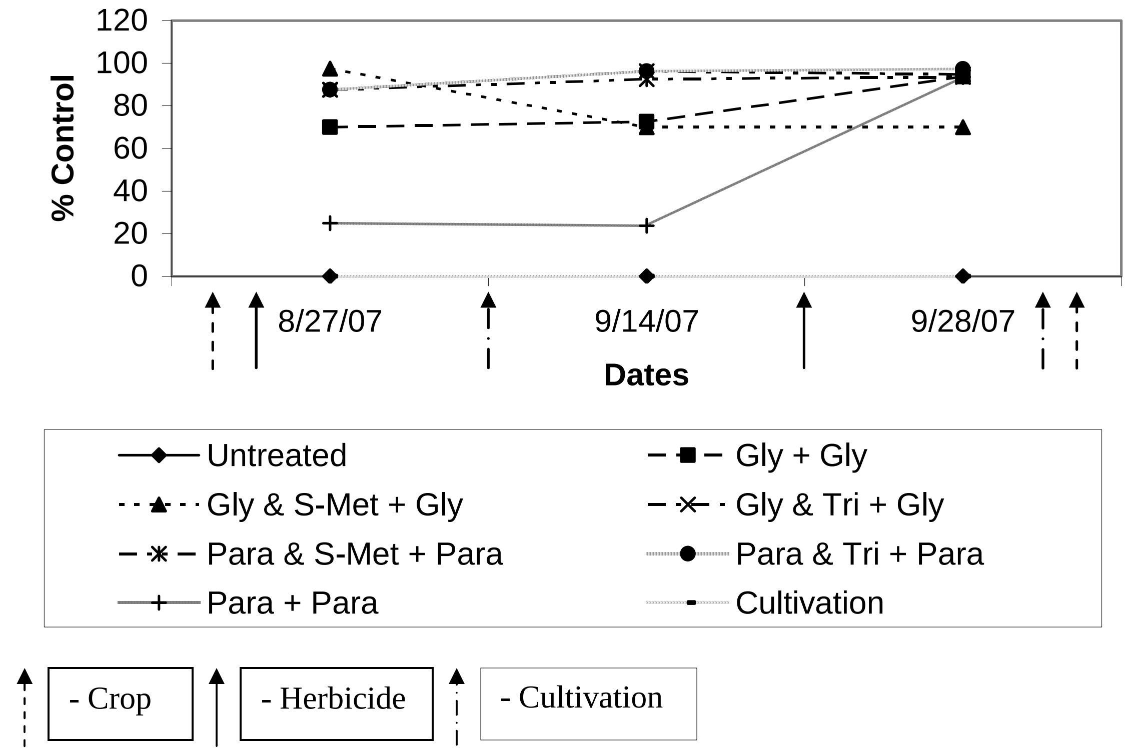


Figure 2-7. Effect of different fallow treatments on the control of yellow nutsedge during the second fallow season in Citra, Fl. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

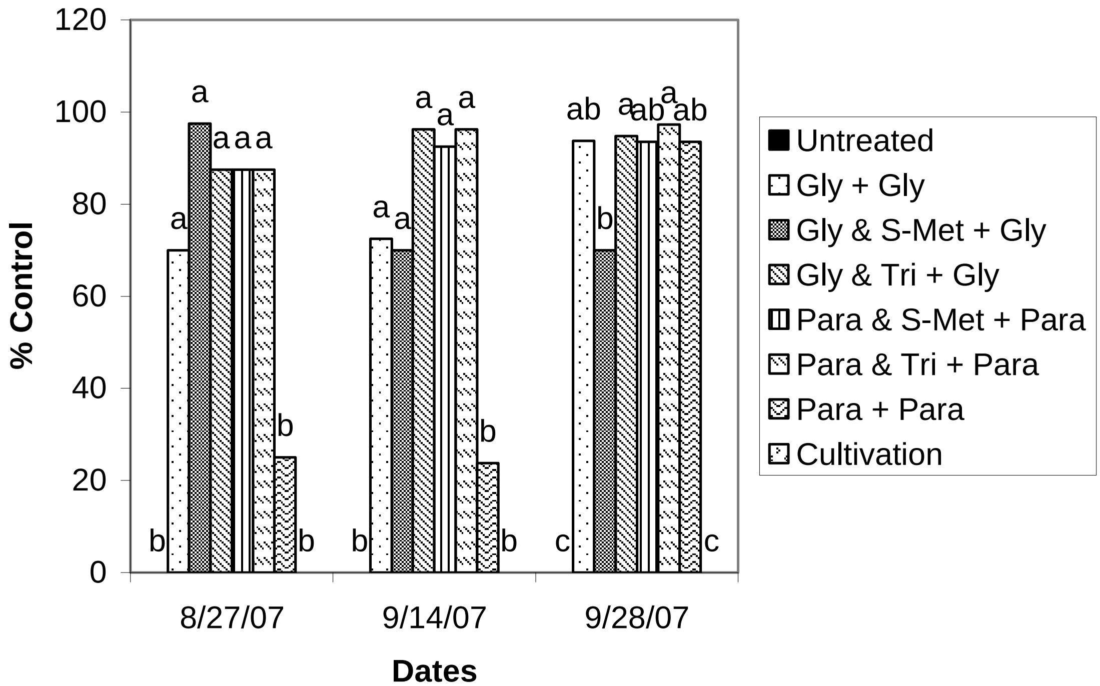


Figure 2-8. Effect of different fallow treatments on the control of yellow nutsedge during the second fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop.

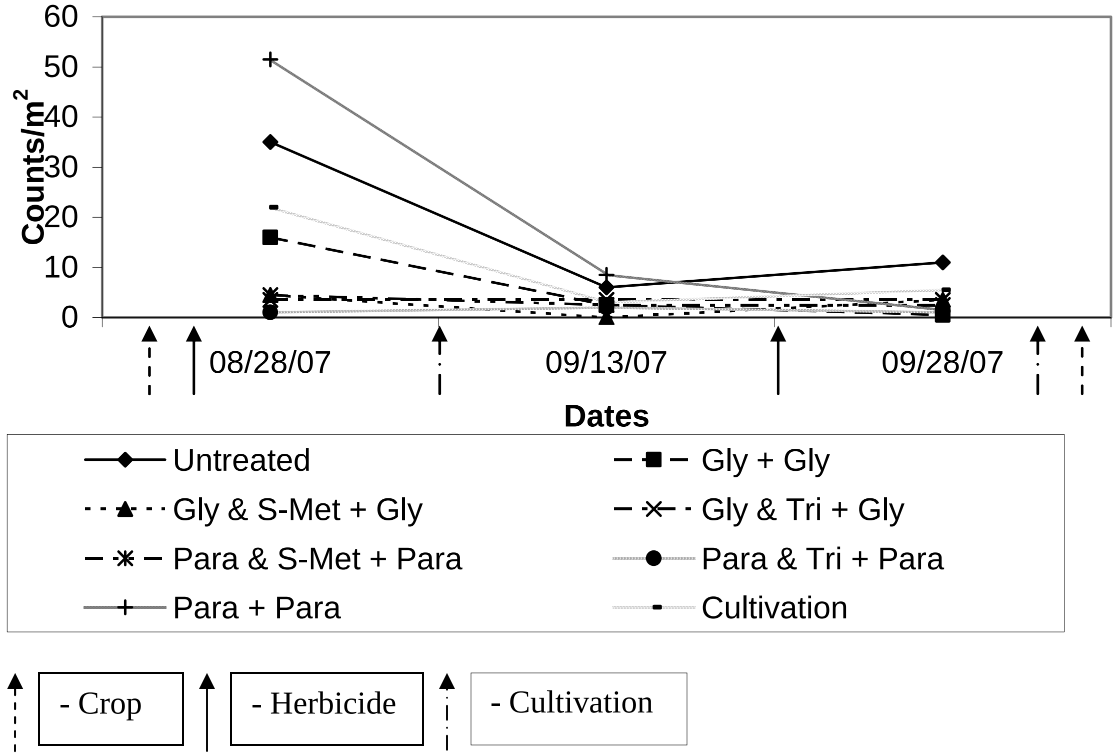


Figure 2-9. Effect of different fallow treatments on the population density of yellow nutsedge during the second fallow season in Citra, Fl. Weed counts include all living plants independent of visual health. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

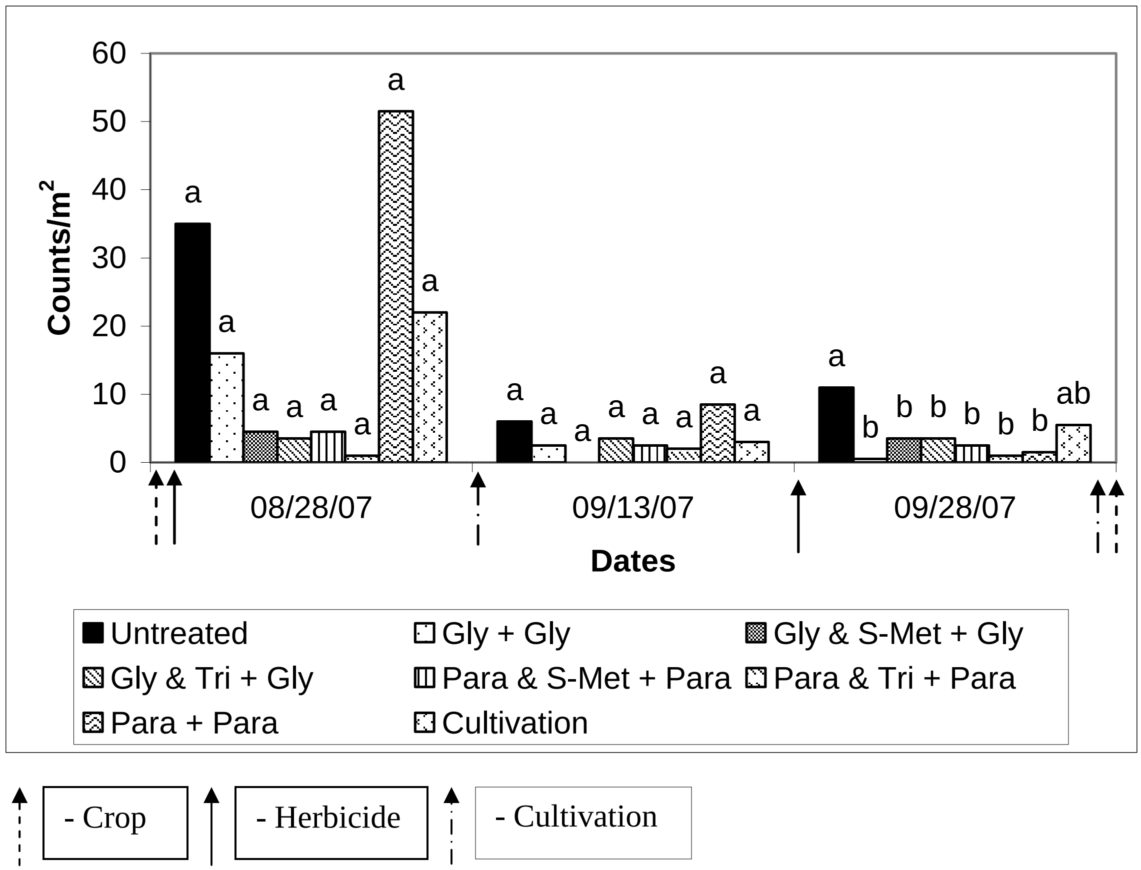


Figure 2-10. Effect of different fallow treatments on the population density of yellow nutsedge during the second fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

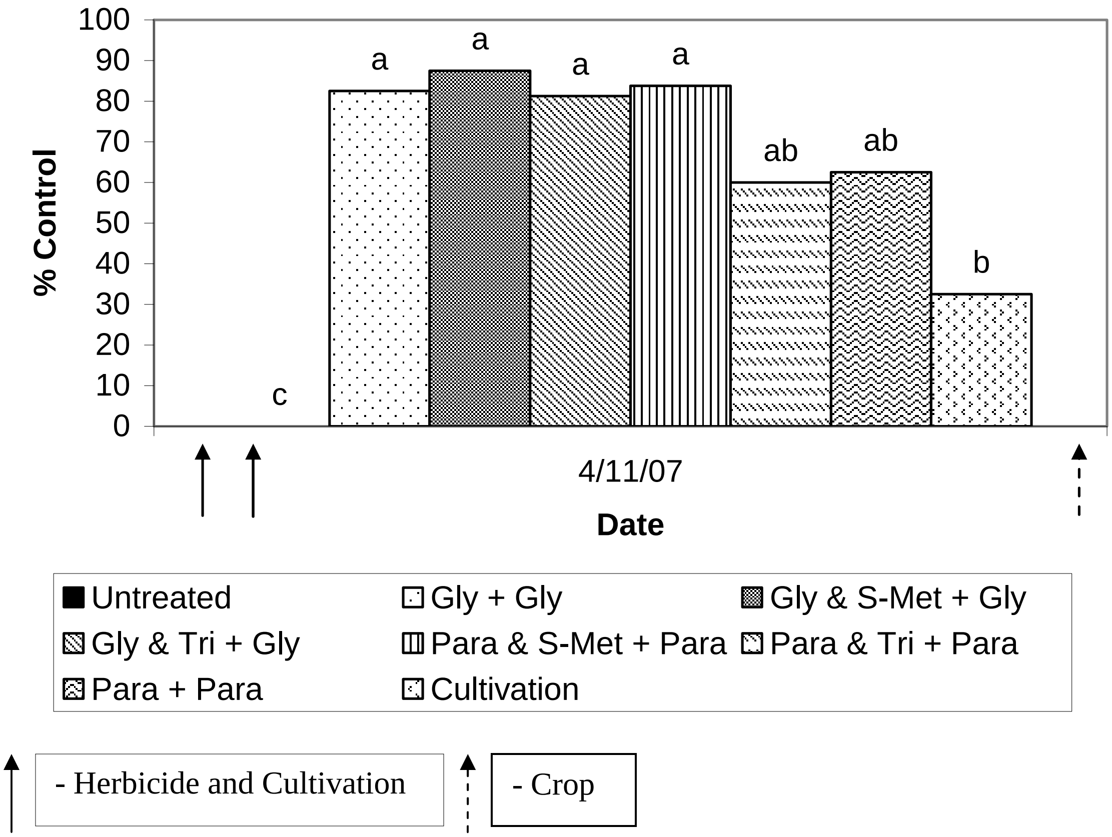


Figure 2-11. Effect of different fallow treatments on the control of large crabgrass during the first fallow season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was only performed in the cultivation treatment plots during the fallow period and no cultivation was implemented during the growing season. Note x axis dates and treatment applications timelines are not drawn to scale.

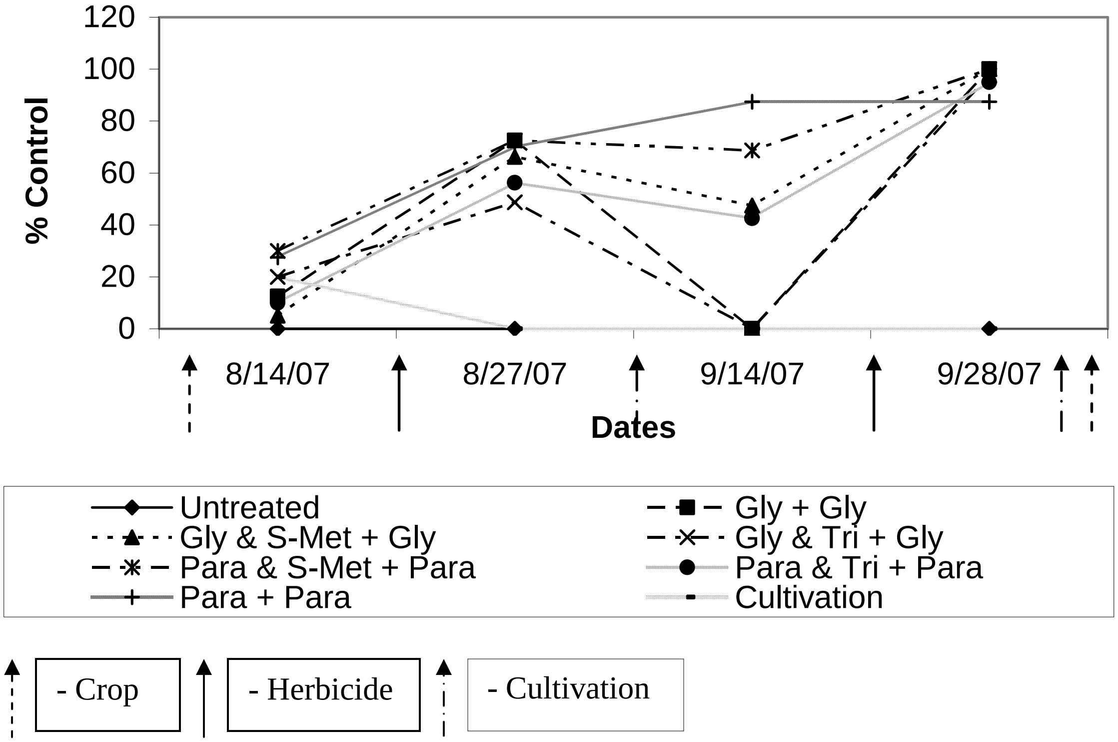


Figure 2-12. Effect of different fallow treatments on the control of large crabgrass during the second fallow season in Citra, Fl. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

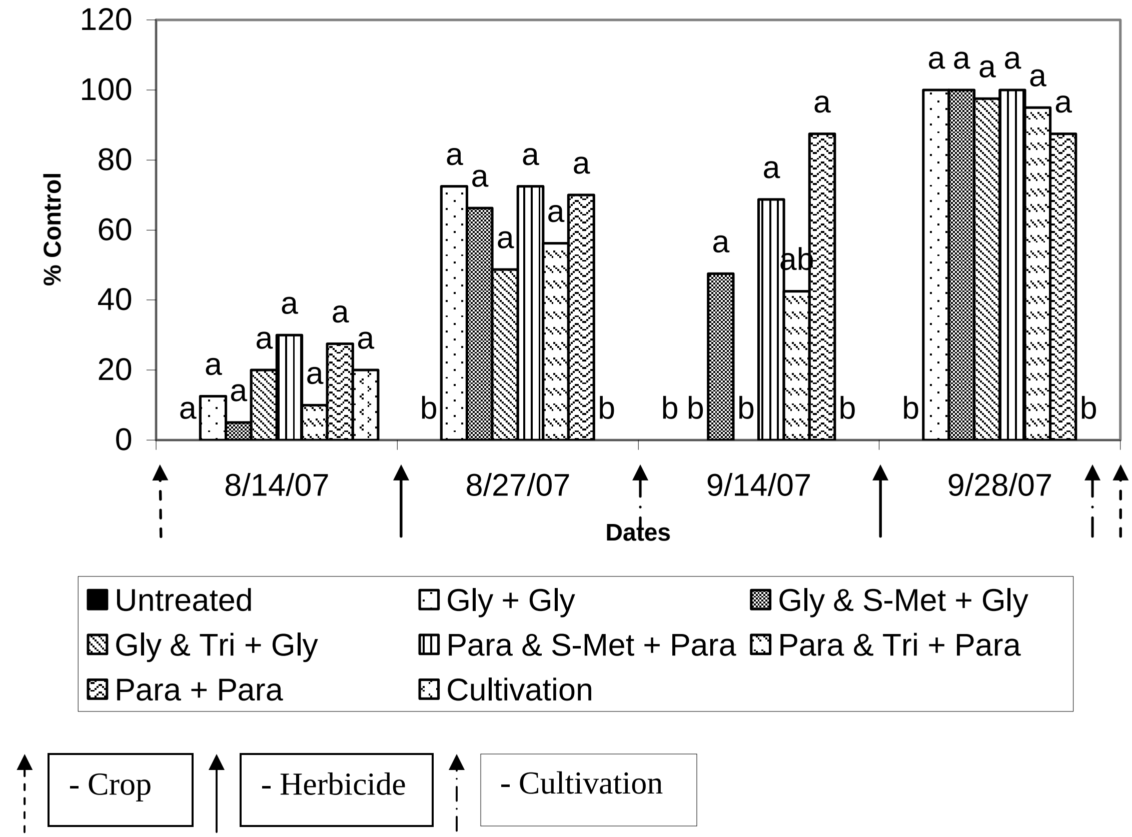


Figure 2-13. Effect of different fallow treatments on the control of large crabgrass during the second fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

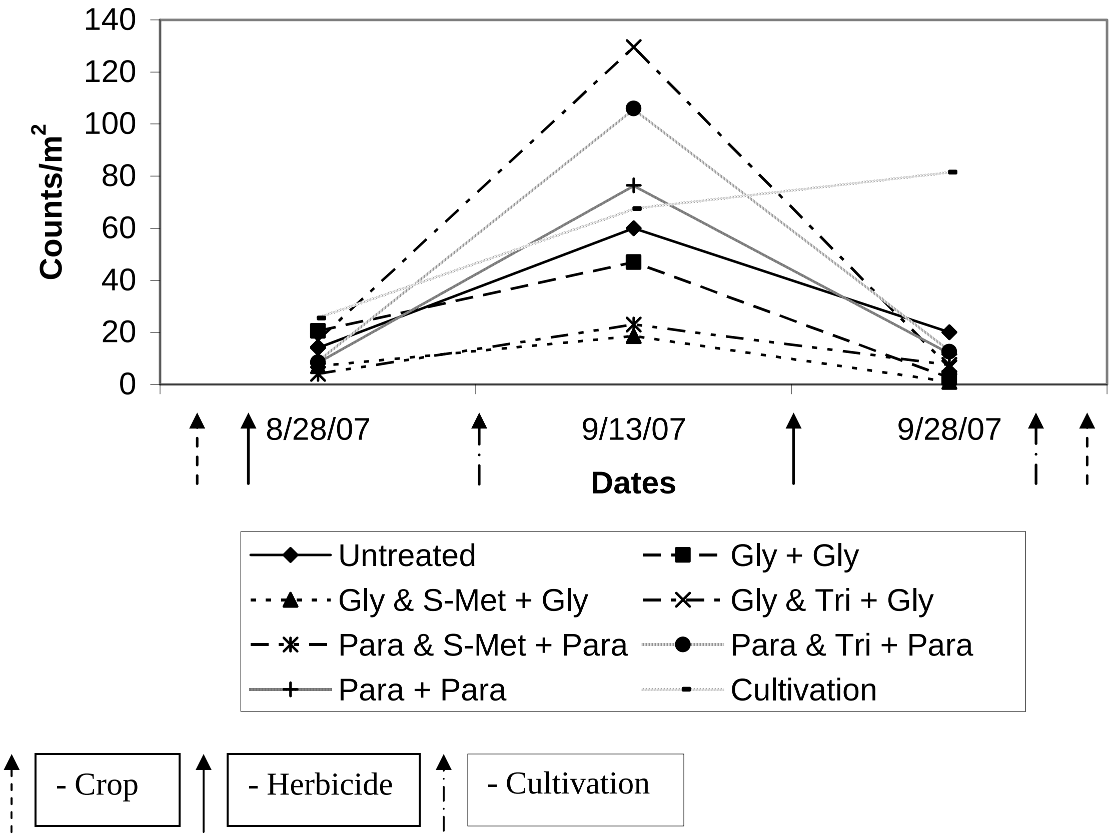


Figure 2-14. Effect of different fallow treatments on the population density of large crabgrass during the second fallow season in Citra, Fl. Weed counts include all living plants independent of visual health. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

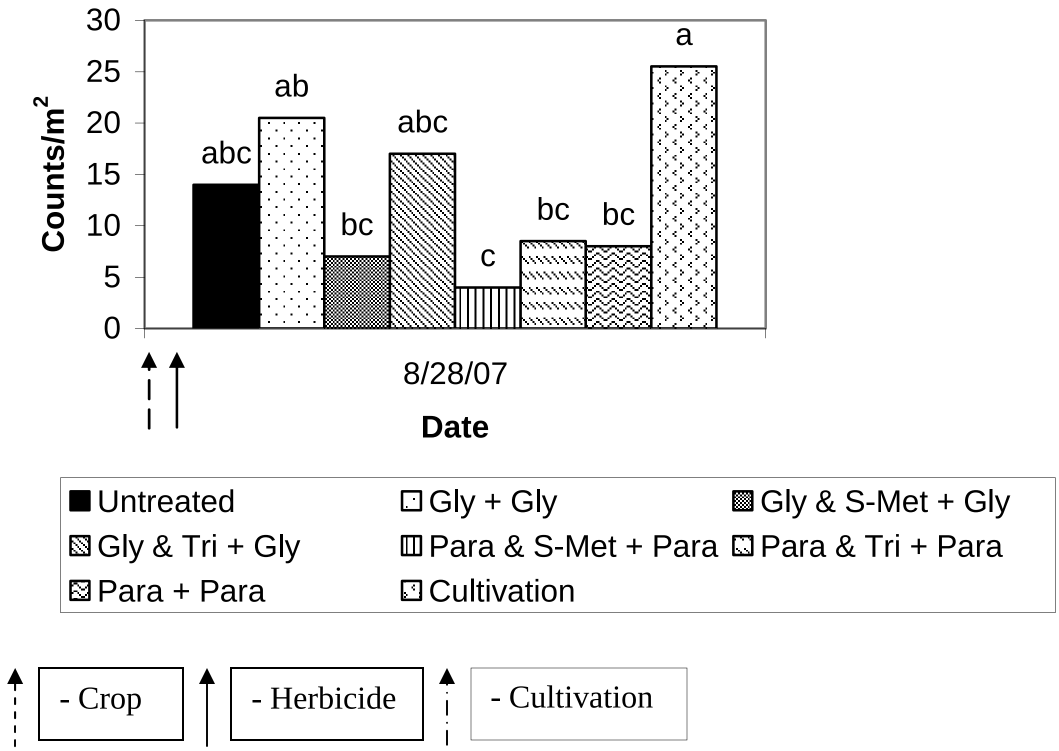


Figure 2-15. Effect of different fallow treatments on the population density of large crabgrass during the second fallow season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

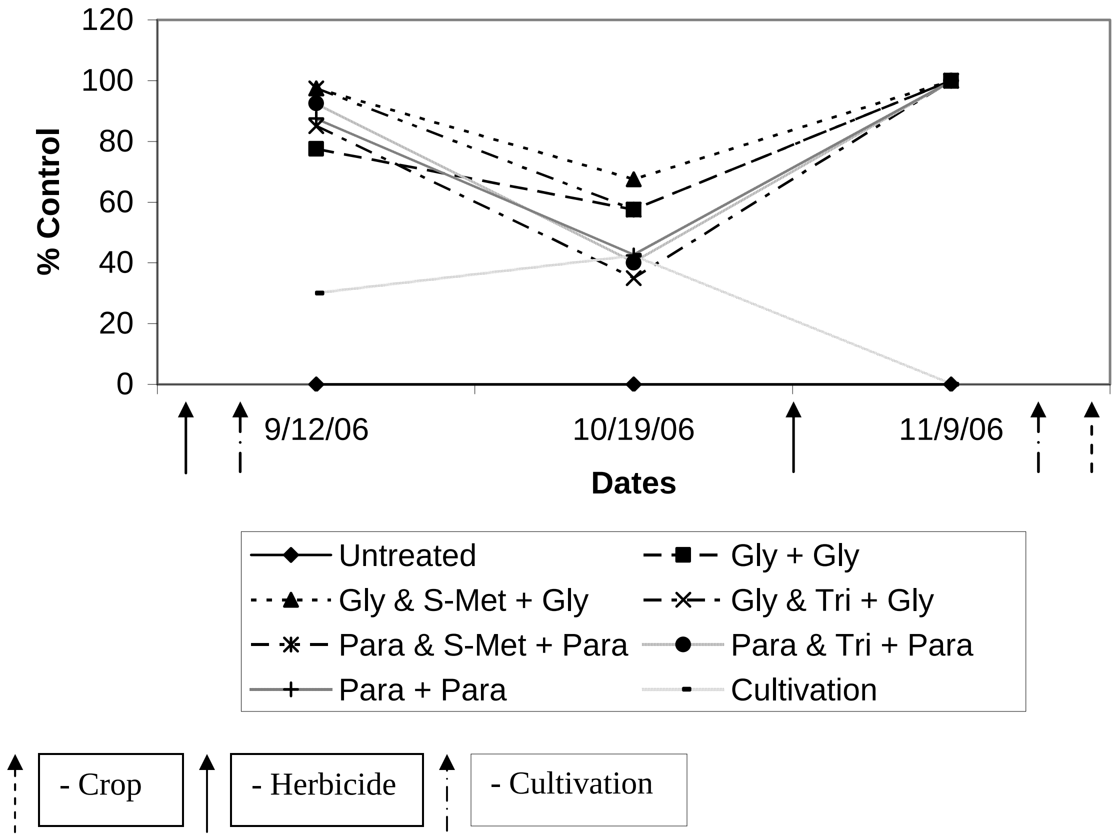


Figure 2-16. Effect of different fallow treatments on the control of goosegrass during the first fallow season in Citra, Fl. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was only performed in the cultivation treatment plots during the fallow period and no cultivation was implemented during the growing season. Note x axis dates and treatment applications timelines are not drawn to scale.

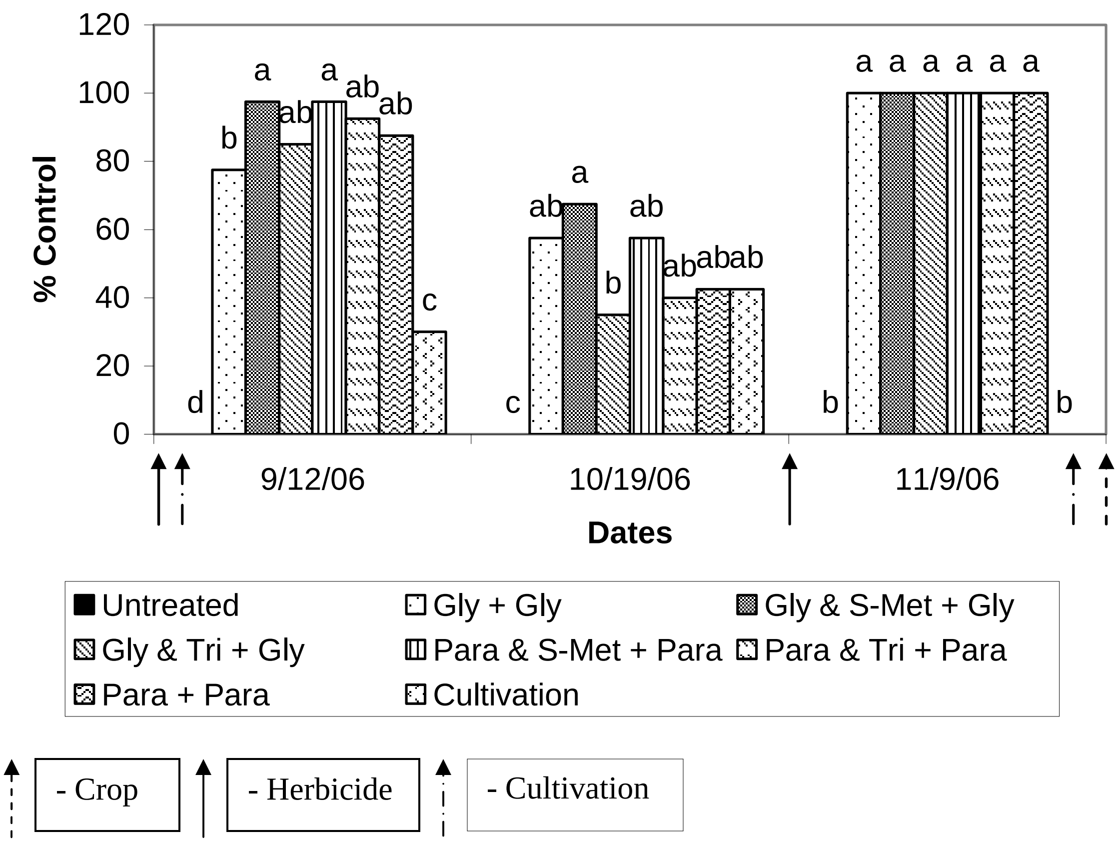


Figure 2-17. Effect of different fallow treatments on the control of goosegrass during the first fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was only performed in the cultivation treatment plots during the fallow period and no cultivation was implemented during the growing season. Note x axis dates and treatment applications timelines are not drawn to scale.

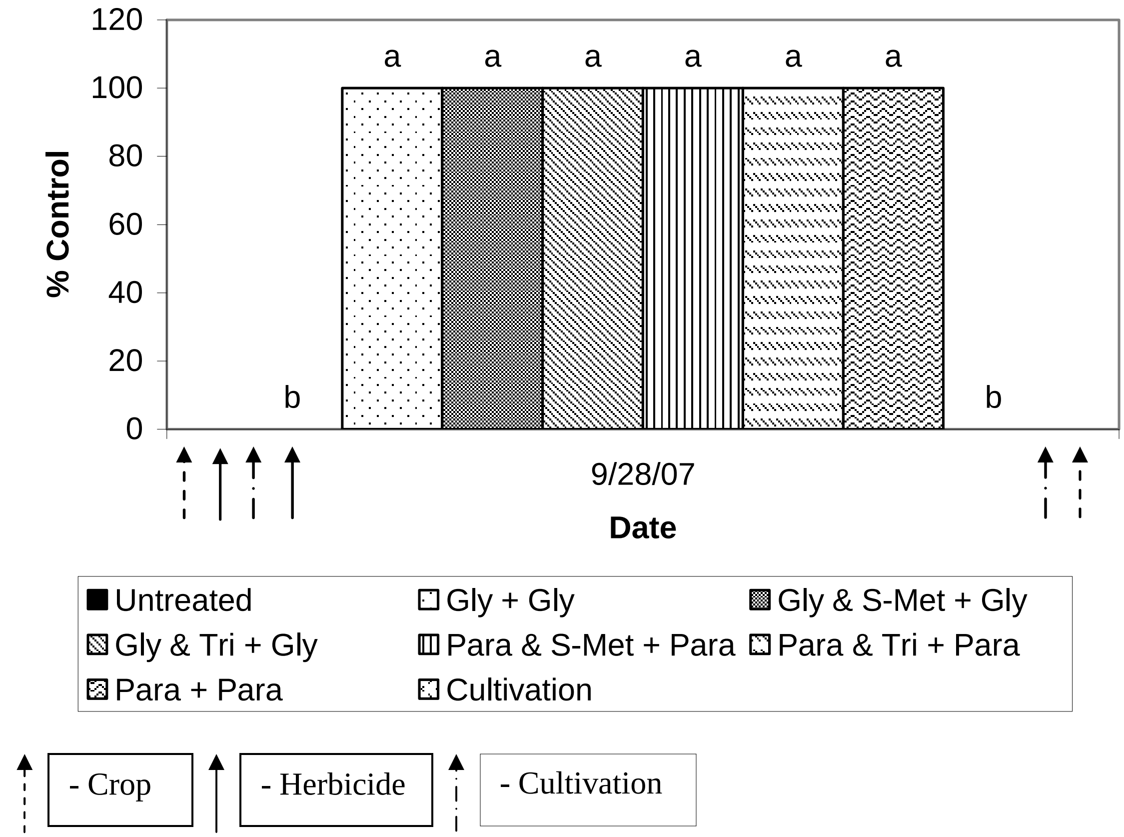


Figure 2-18. Effect of different fallow treatments on the control of goosegrass during the second fallow season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

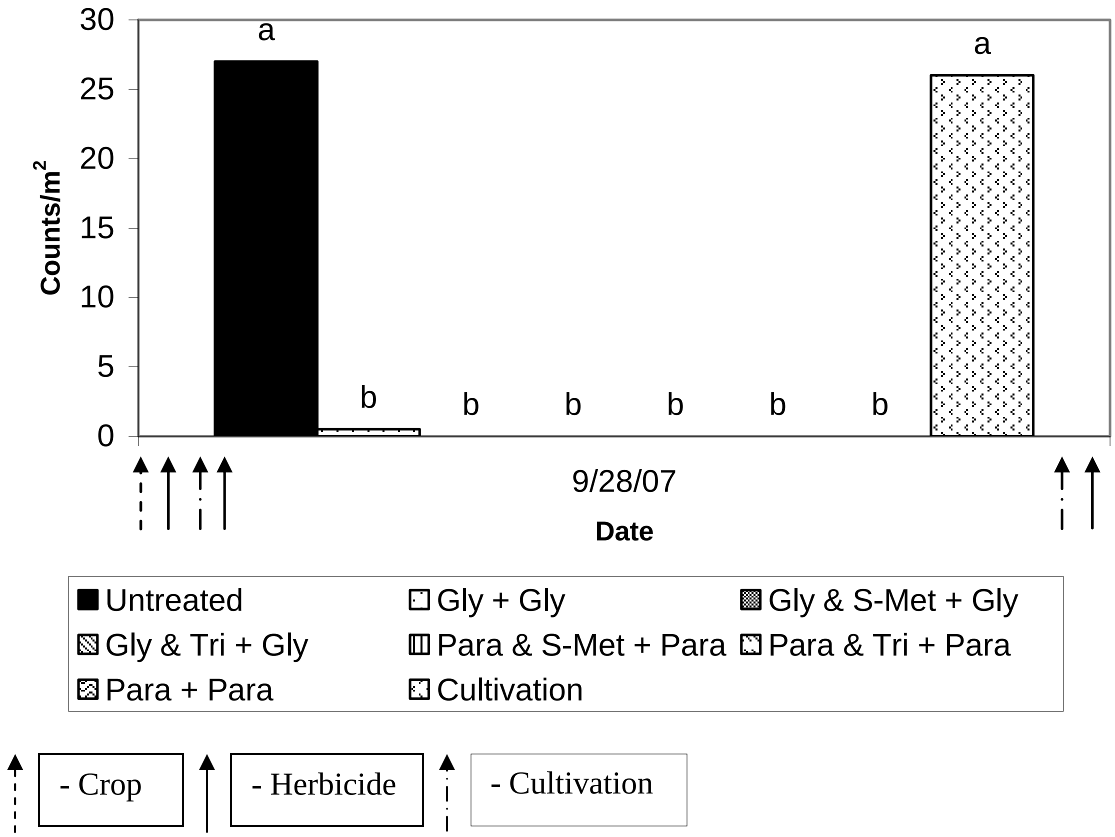


Figure 2-19. Effect of different fallow treatments on the population density of goosegrass during the second fallow season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

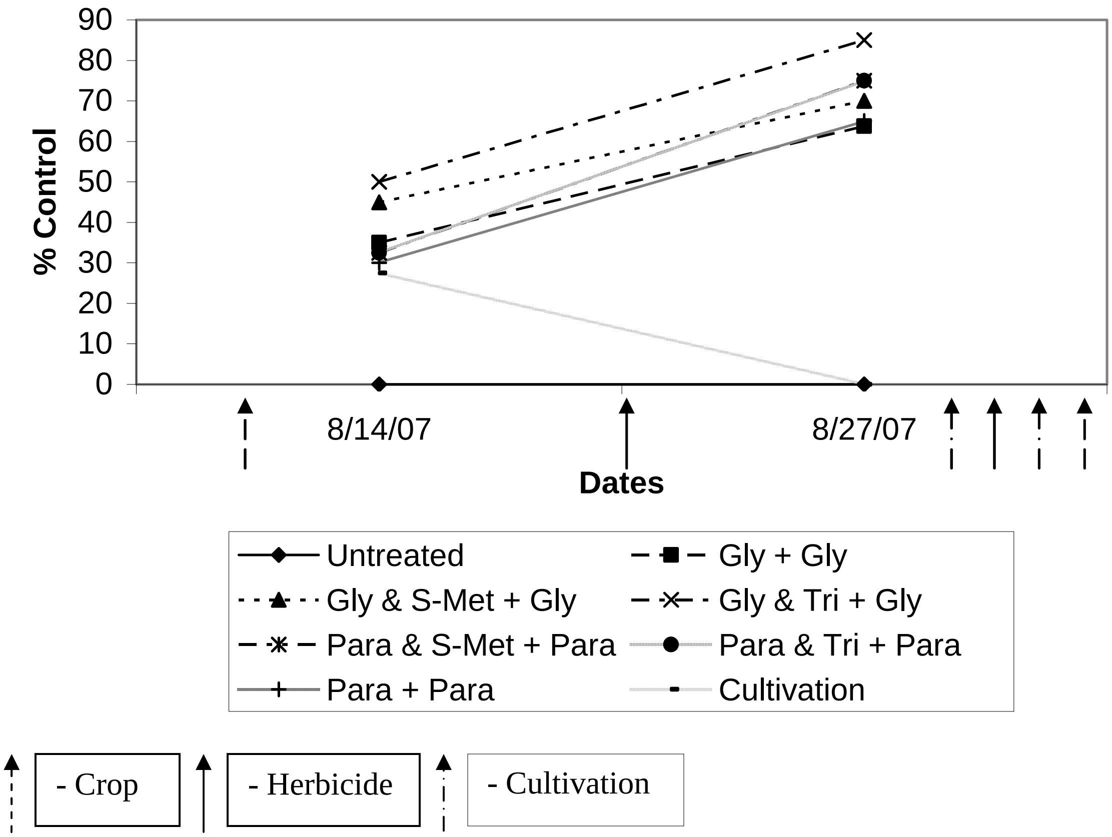


Figure 2-20. Effect of different fallow treatments on the control of volunteer corn plants during the second fallow season in Citra, Fl. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

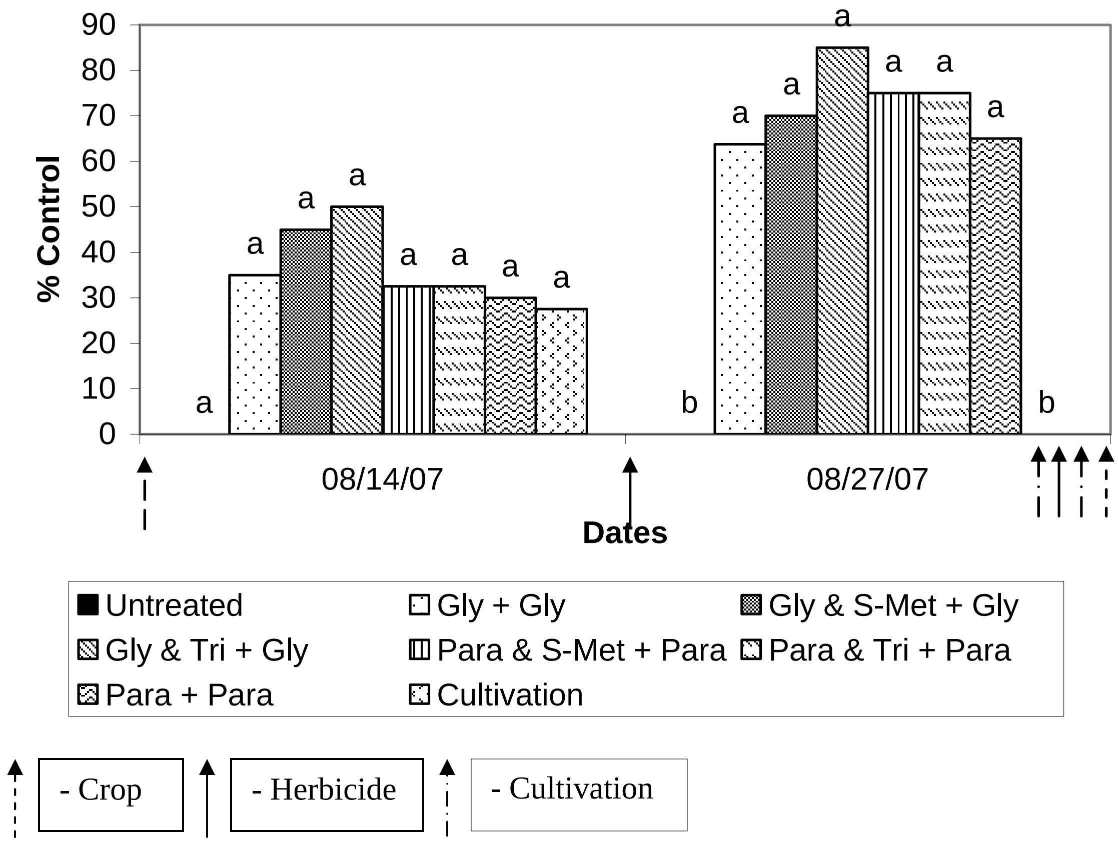


Figure 2-21. Effect of different fallow treatments on the control of volunteer corn plants during the second fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

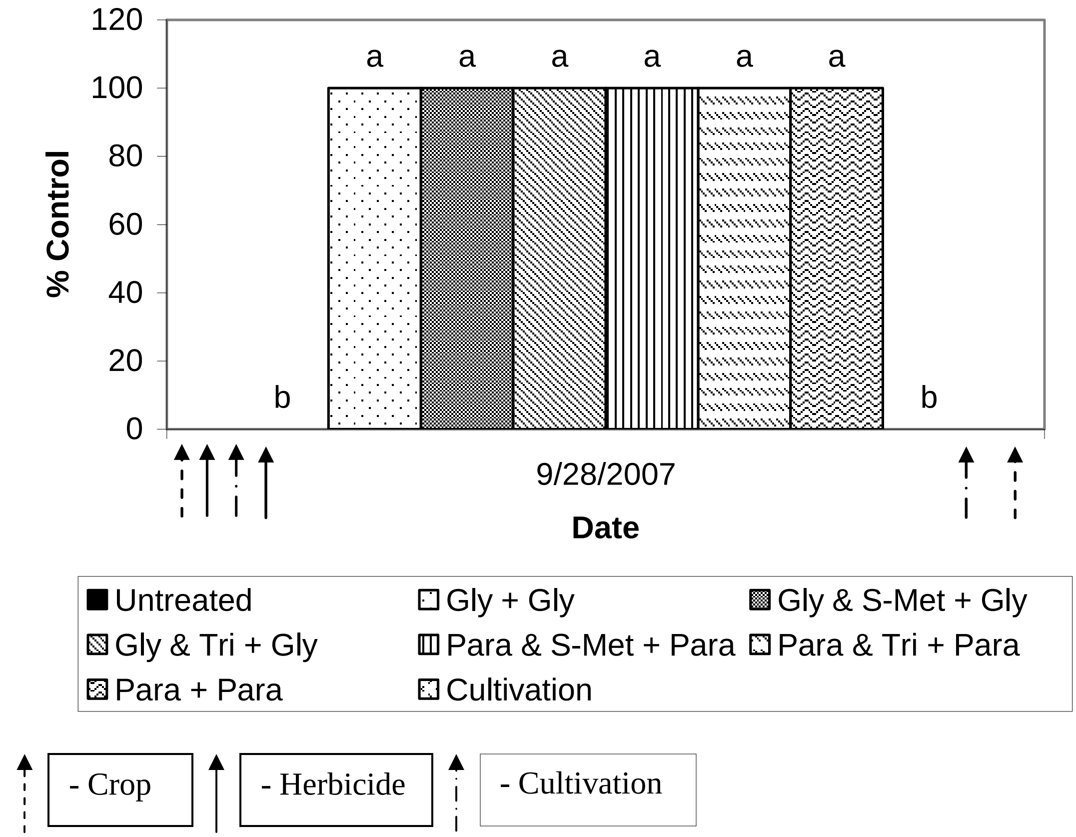


Figure 2-22. Effect of different fallow treatments on the control of crowfootgrass plants during the second fallow season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

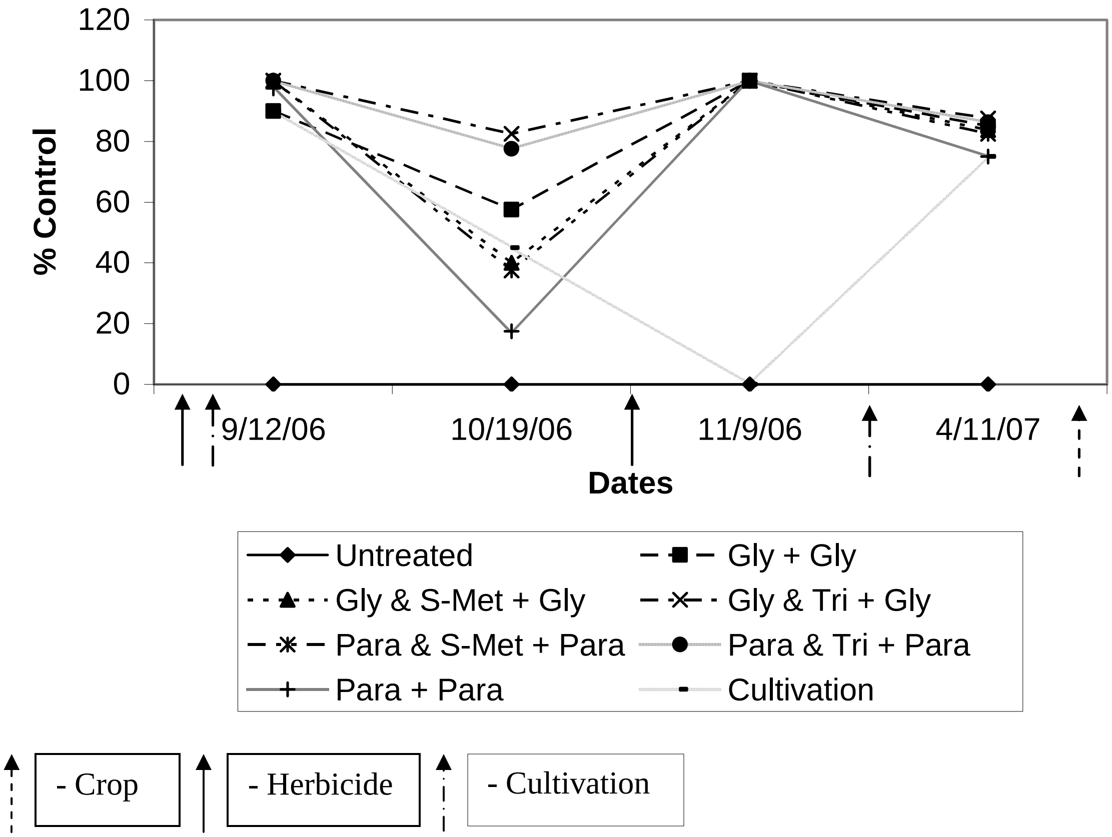


Figure 2-23. Effect of different fallow treatments on the control of amaranth during the first fallow season in Citra, Fl. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was only performed in the cultivation treatment plots during the fallow period and no cultivation was implemented during the growing season. Note x axis dates and treatment applications timelines are not drawn to scale.

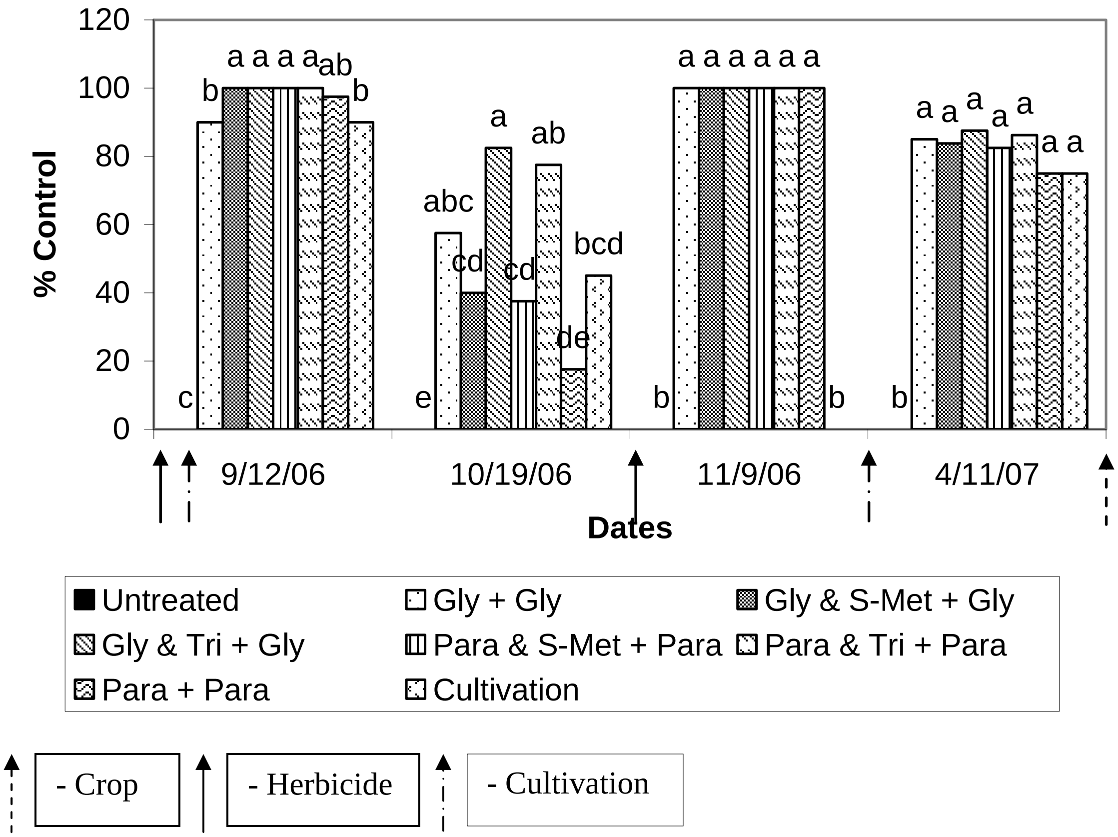


Figure 2-24. Effect of different fallow treatments on the control of amaranth during the first fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was only performed in the cultivation treatment plots during the fallow period and no cultivation was implemented during the growing season. Note x axis dates and treatment applications timelines are not drawn to scale.

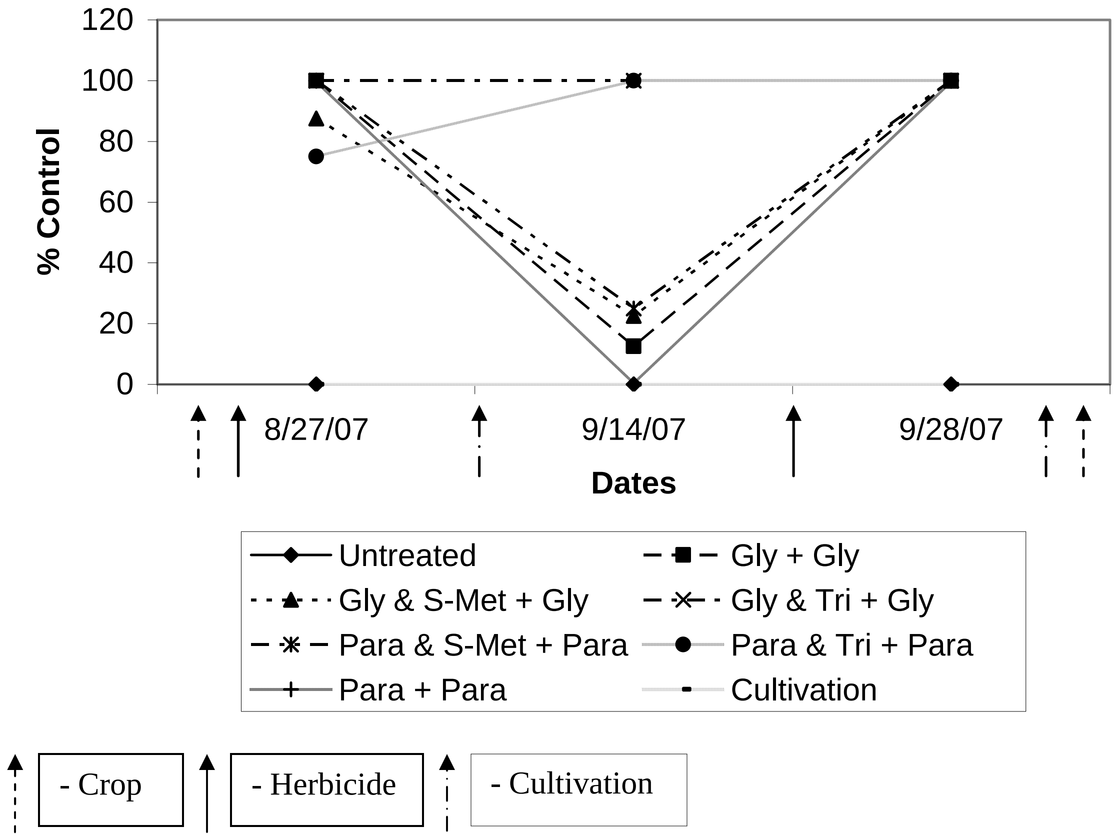


Figure 2-25. Effect of different fallow treatments on the control of amaranth plants during the second fallow season in Citra, Fl. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

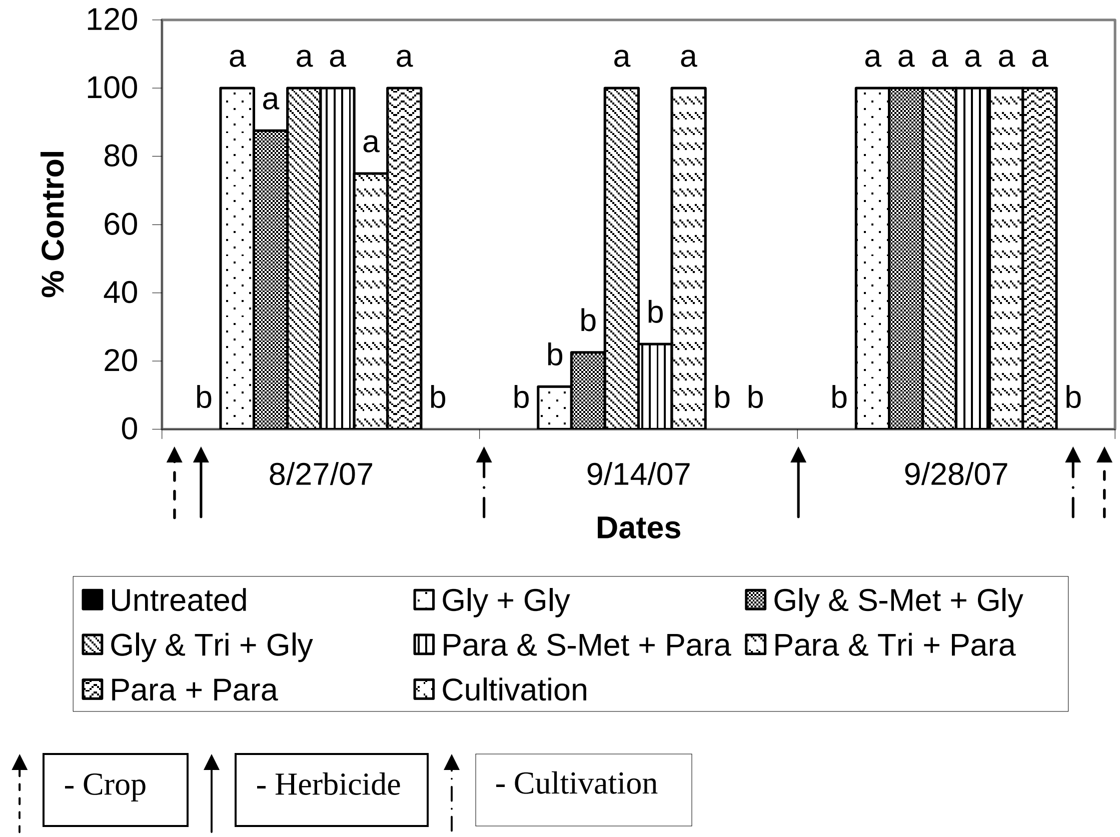


Figure 2-26. Effect of different fallow treatments on the control of amaranth plants during the second fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

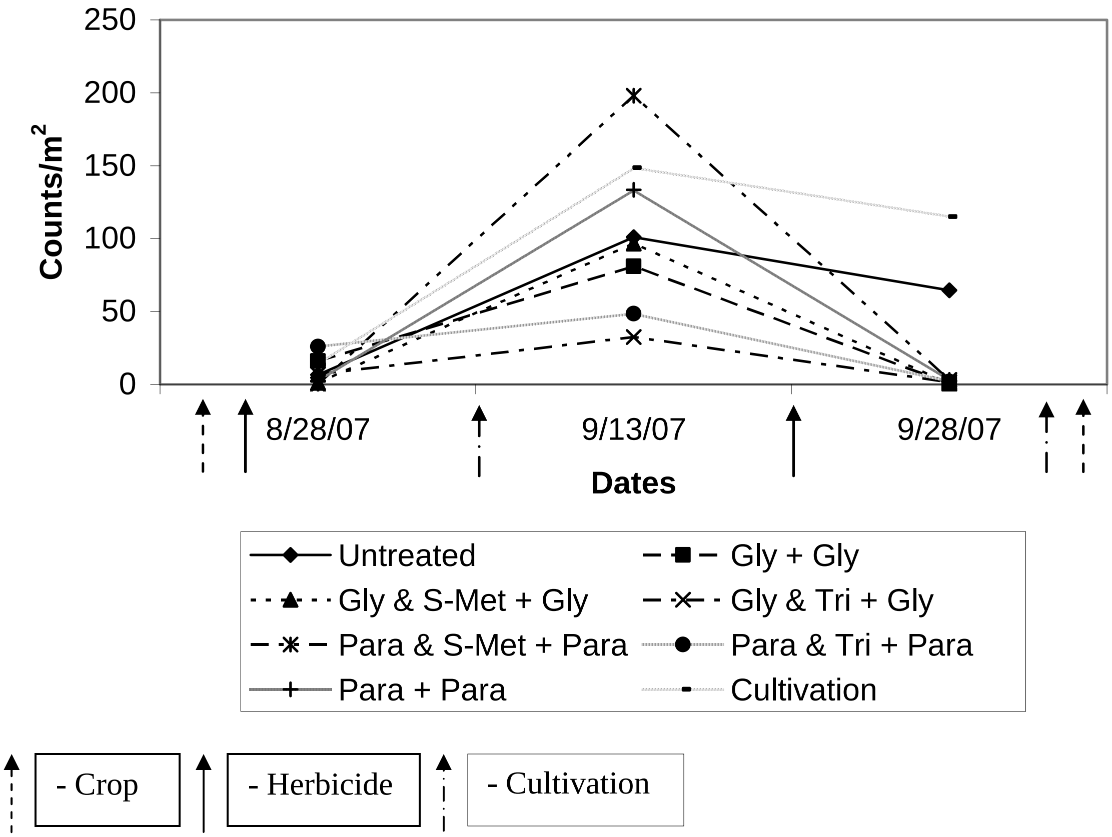


Figure 2-27. Effect of different fallow treatments on the population density of amaranth during the second fallow season in Citra, Fl. Weed counts include all living plants independent of visual health. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

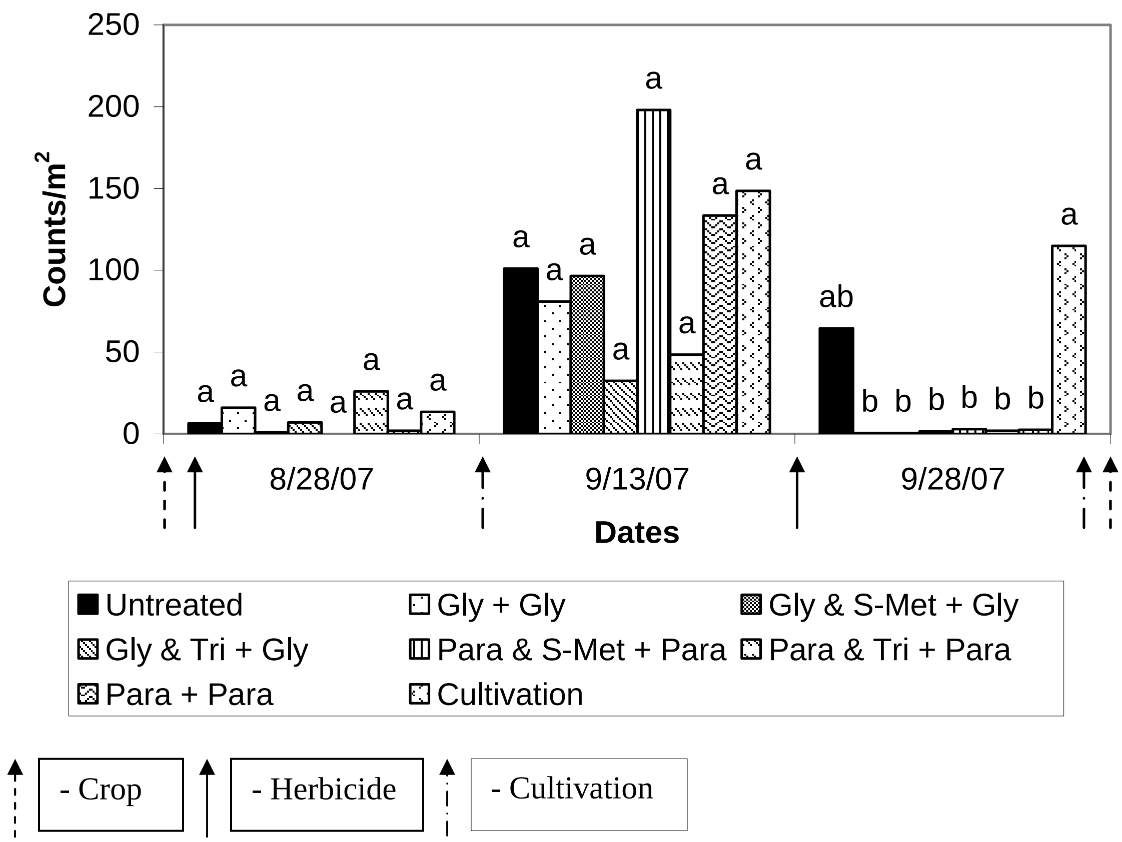


Figure 2-28. Effect of different fallow treatments on the population density of amaranth during the second fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

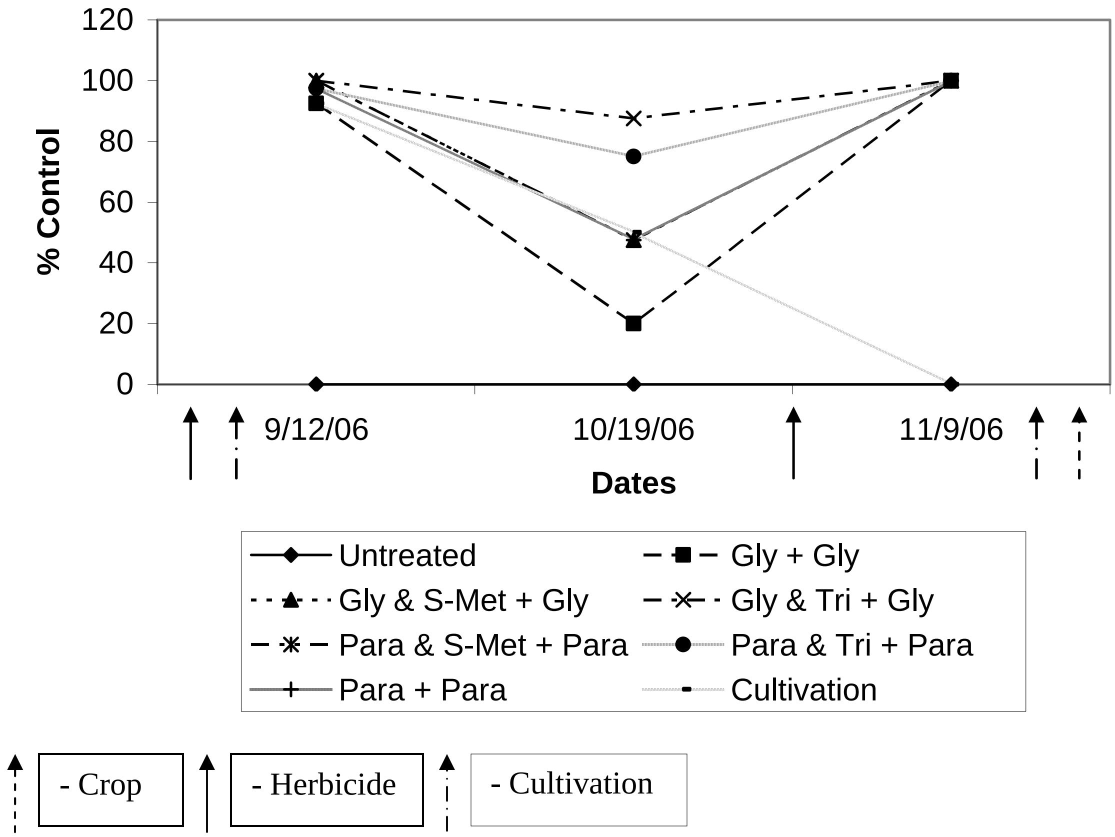


Figure 2-29. Effect of different fallow treatments on the control of common purslane during the first fallow season in Citra, Fl. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was only performed in the cultivation treatment plots during the fallow period and no cultivation was implemented during the growing season. Note x axis dates and treatment applications timelines are not drawn to scale.

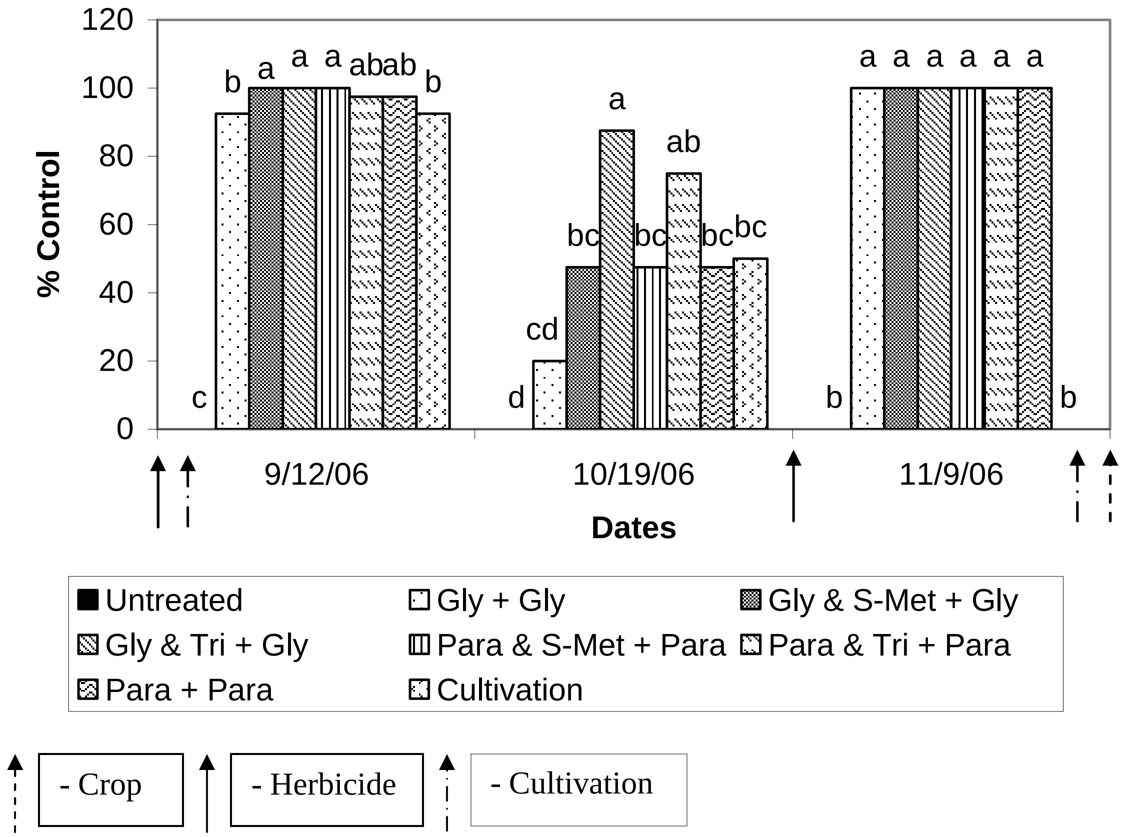


Figure 2-30. Effect of different fallow treatments on the control of common purslane during the first fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was only performed in the cultivation treatment plots during the fallow period and no cultivation was implemented during the growing season. Note x axis dates and treatment applications timelines are not drawn to scale.

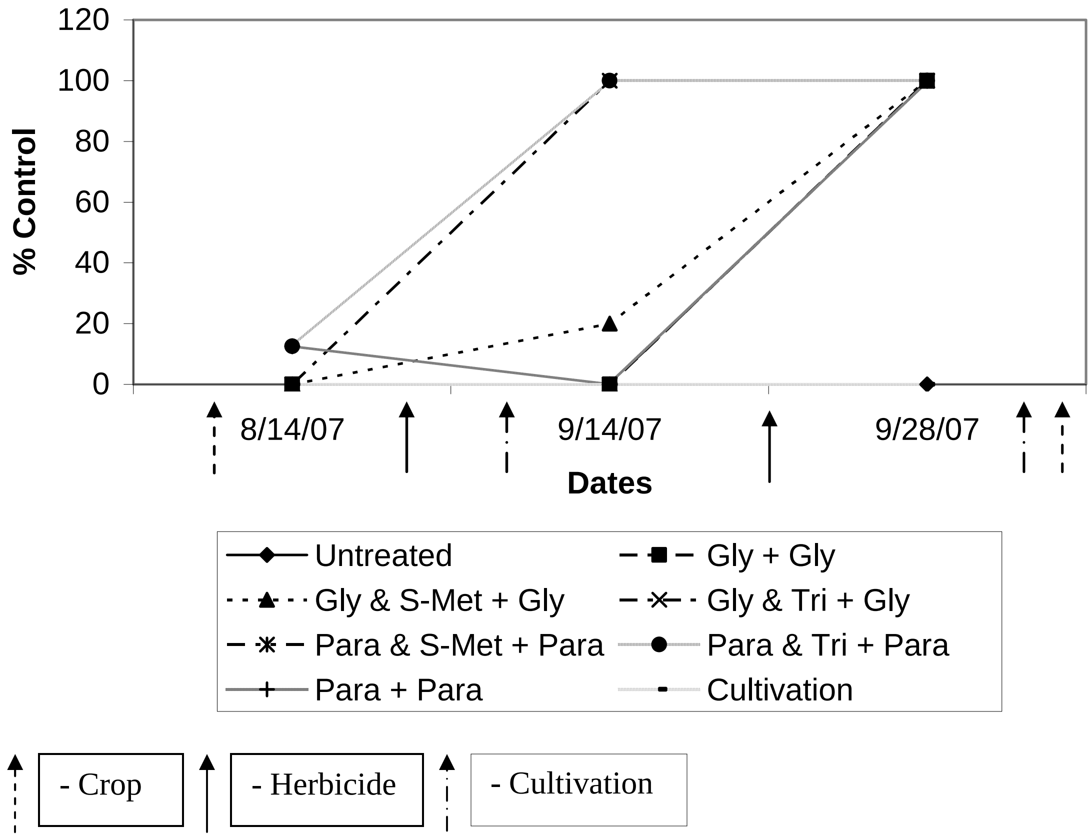


Figure 2-31. Effect of different fallow treatments on the control of purslane plants during the second fallow season in Citra, Fl. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

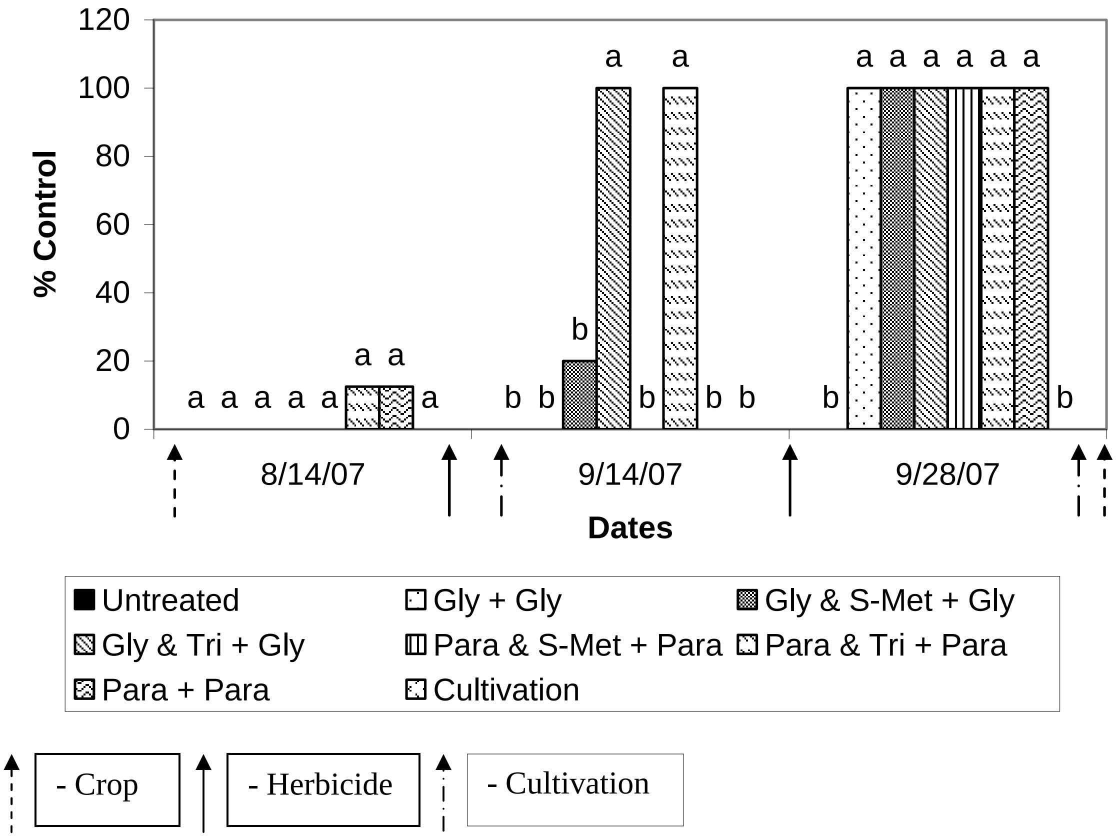


Figure 2-32. Effect of different fallow treatments on the control of purslane plants during the second fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

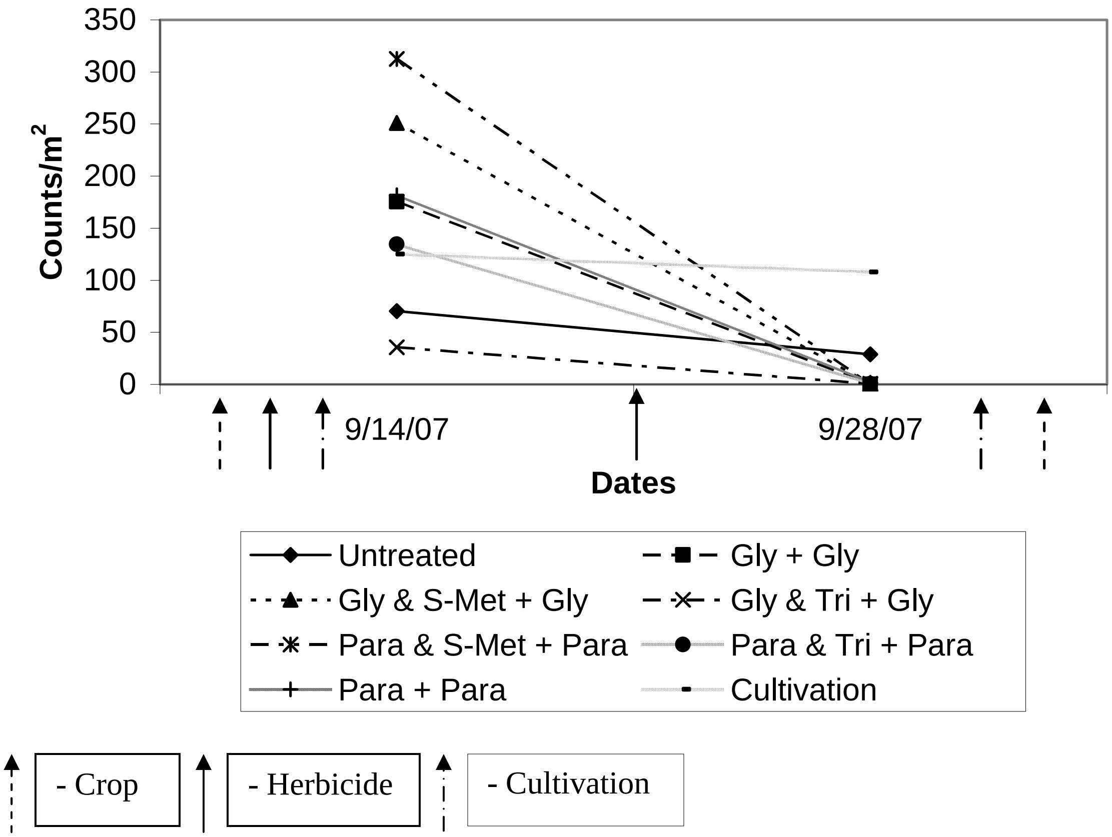


Figure 2-33. Effect of different fallow treatments on the population density of purslane during the second fallow season in Citra, Fl. Weed counts include all living plants independent of visual health. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

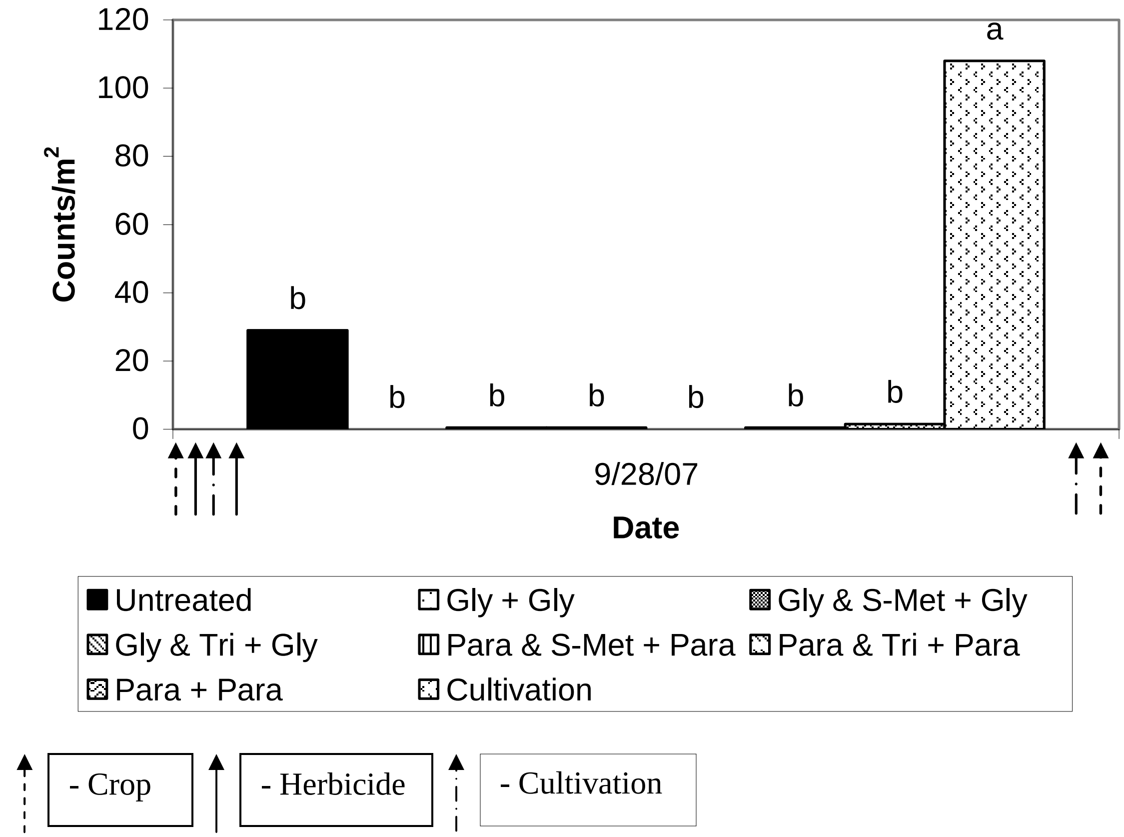


Figure 2-34. Effect of different fallow treatments on the population density of purslane during the second fallow season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

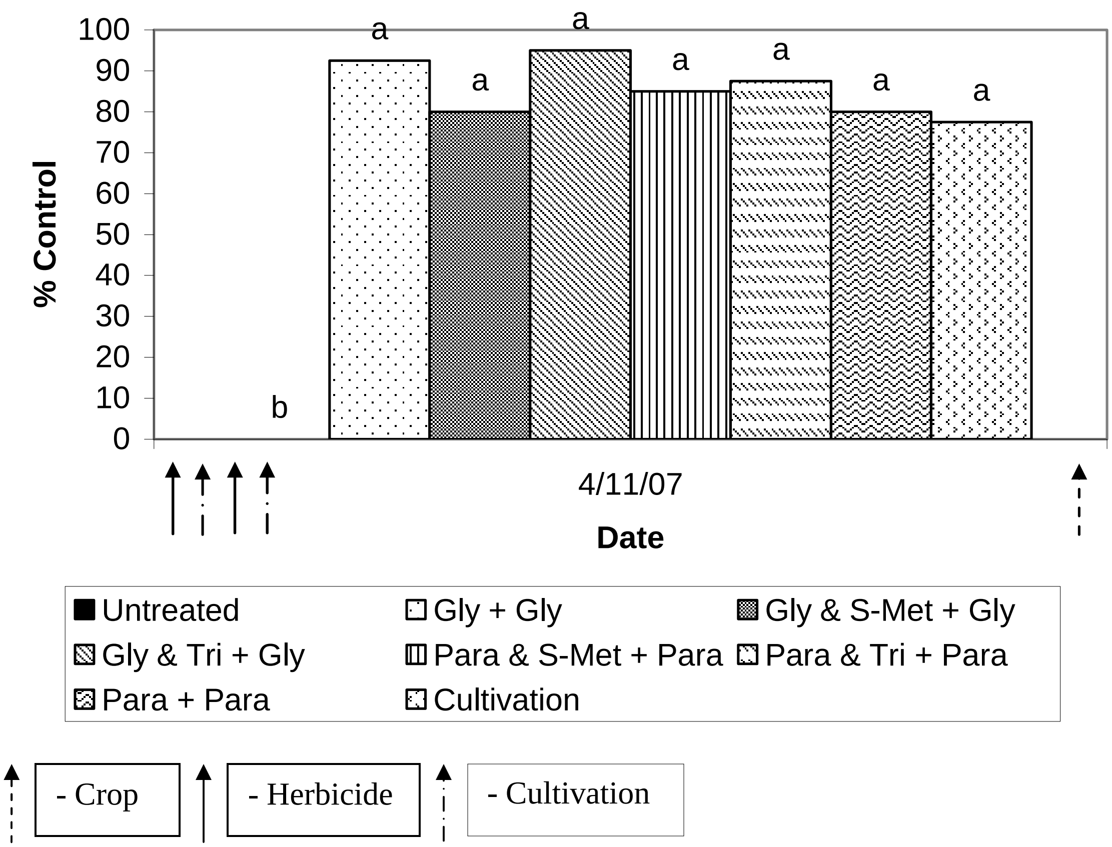


Figure 2-35. Effect of different fallow treatments on the control of Florida pusley during the first fallow season in Citra, Fl. Means followed by the same letter date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was only performed in the cultivation treatment plots during the fallow period and no cultivation was implemented during the growing season. Note x axis dates and treatment applications timelines are not drawn to scale.

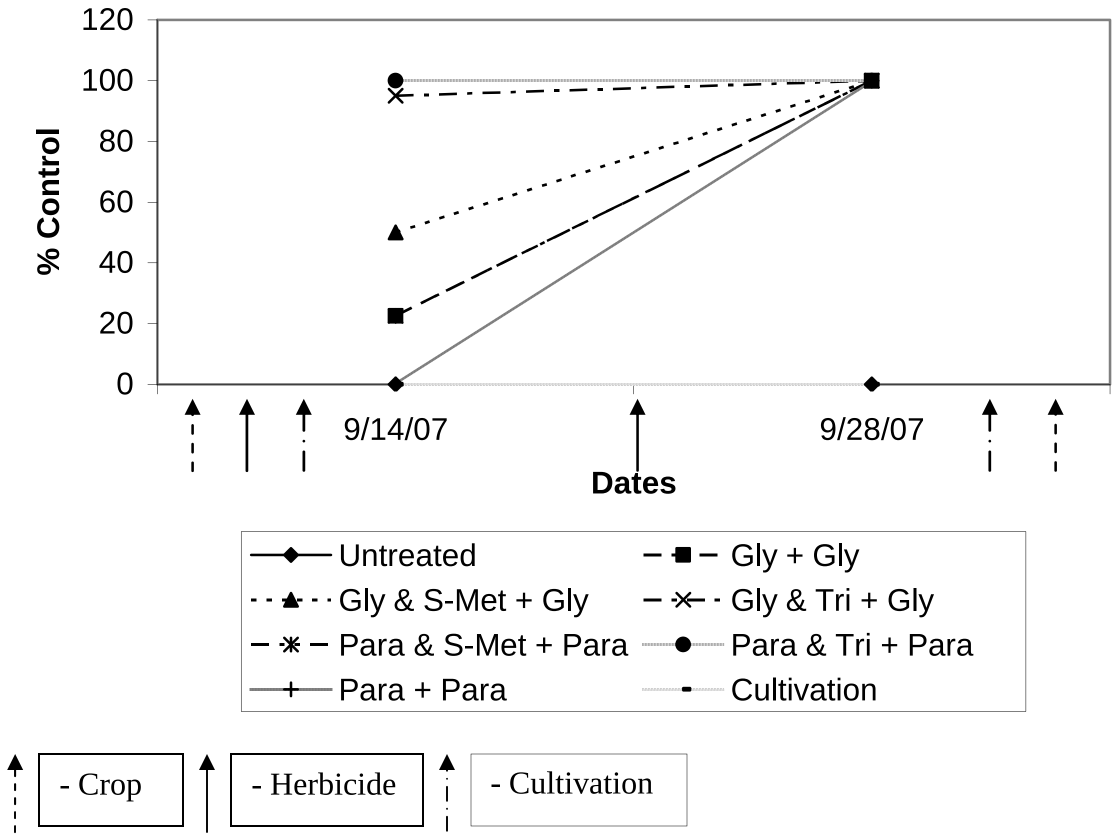


Figure 2-36. Effect of different fallow treatments on the control of Florida pusley plants during the second fallow season in Citra, Fl. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

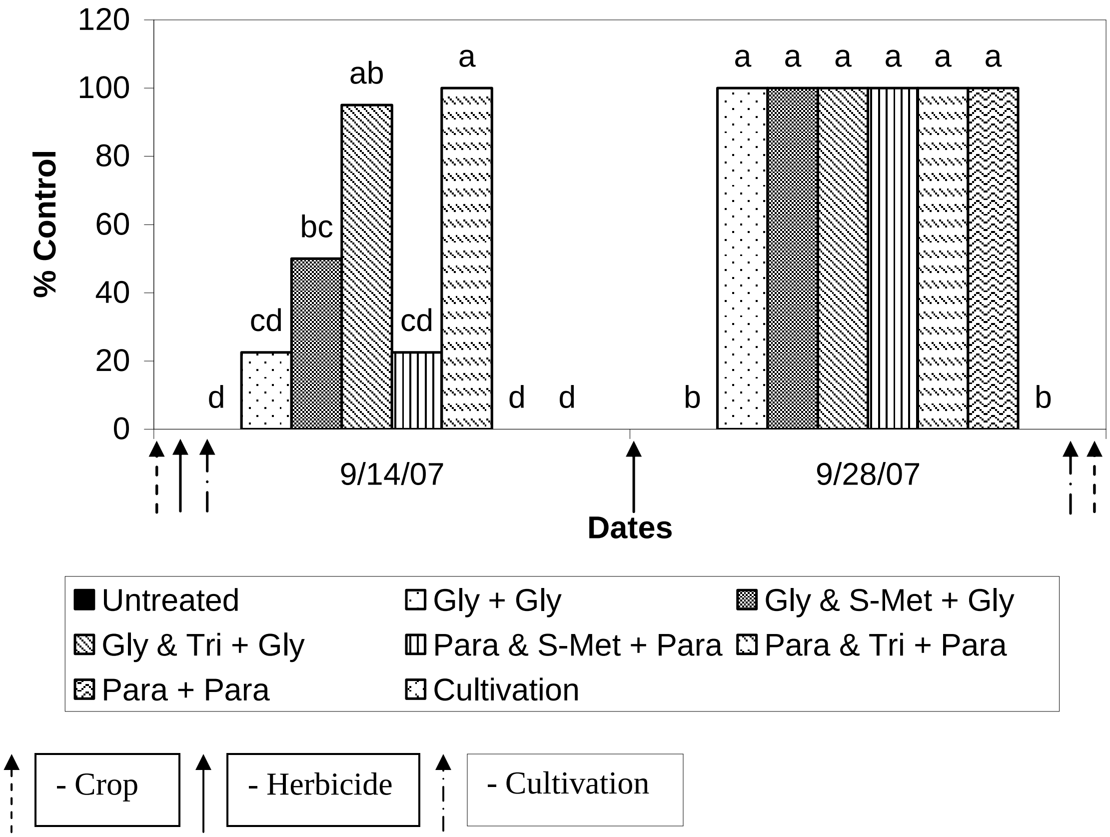


Figure 2-37. Effect of different fallow treatments on the control of Florida pusley plants during the second fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

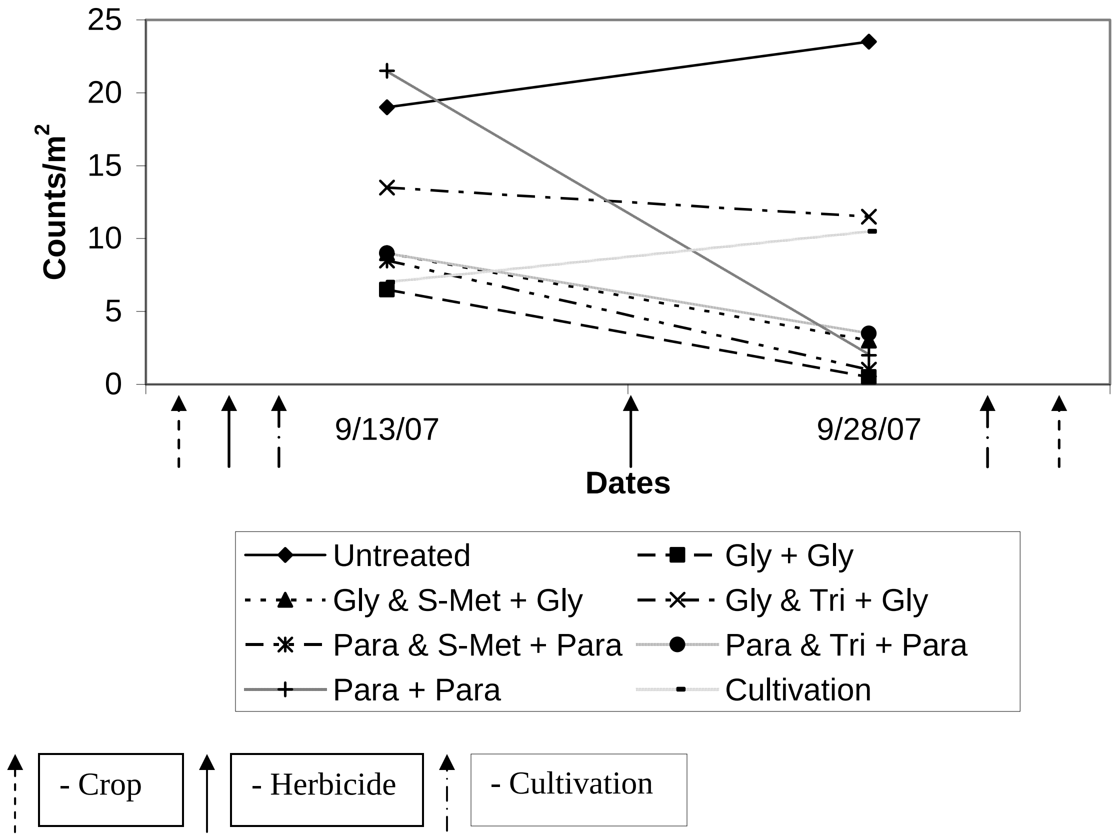


Figure 2-38. Effect of different fallow treatments on the population density of Florida pusley during the second fallow season in Citra, Fl. Weed counts include all living plants independent of visual health. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

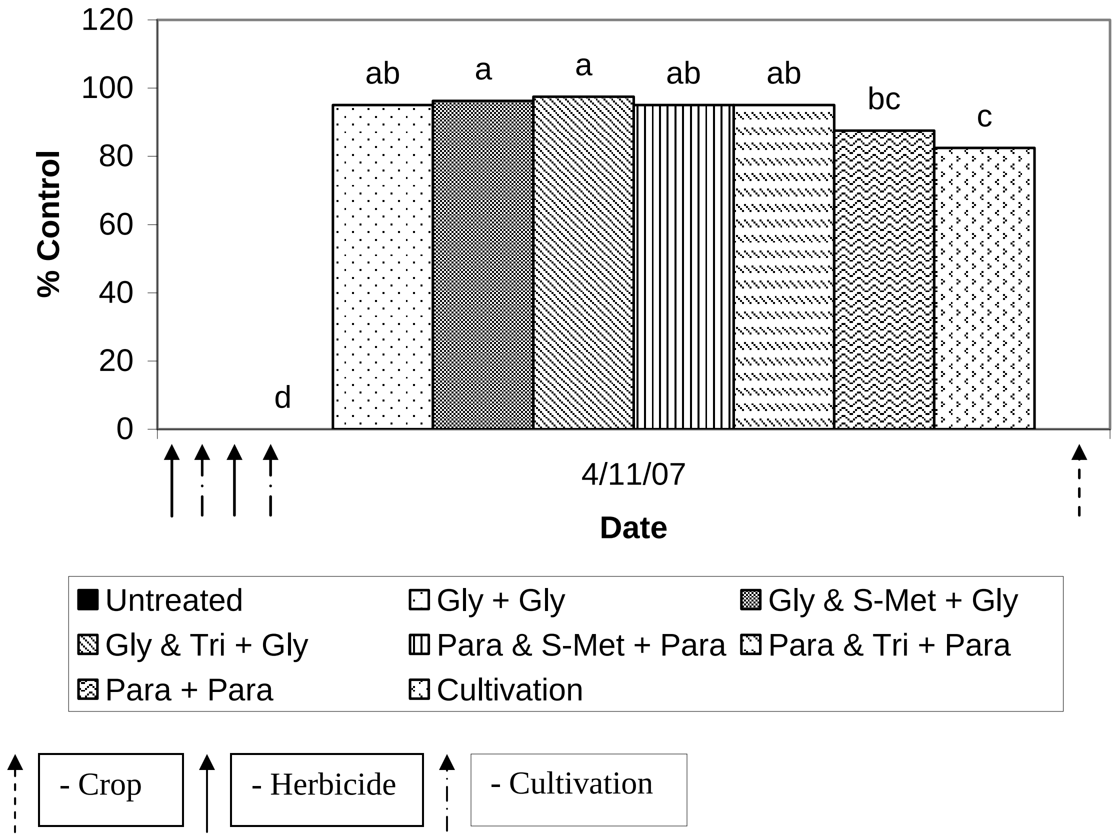


Figure 2-39. Effect of different fallow treatments on the control of cutleaf evening primrose during the first fallow season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was only performed in the cultivation treatment plots during the fallow period and no cultivation was implemented during the growing season. Note x axis dates and treatment applications timelines are not drawn to scale.

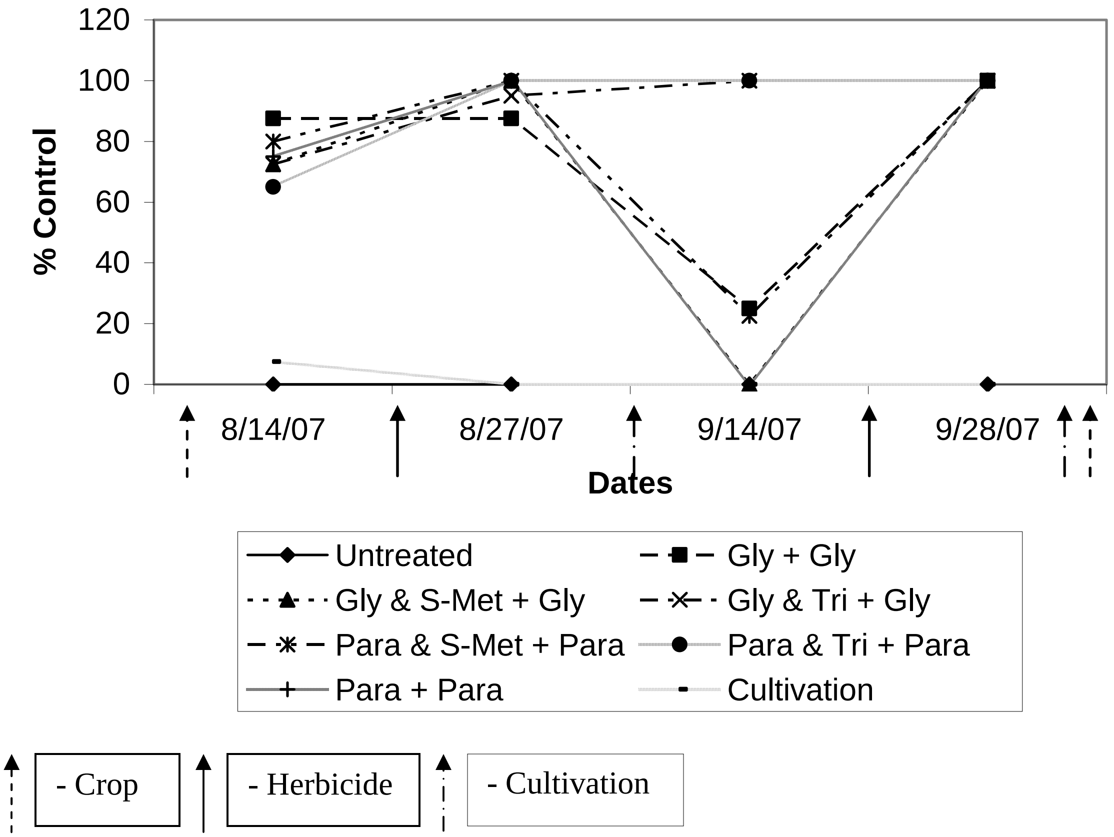


Figure 2-40. Effect of different fallow treatments on the control of cutleaf ground cherry plants during the second fallow season in Citra, Fl. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

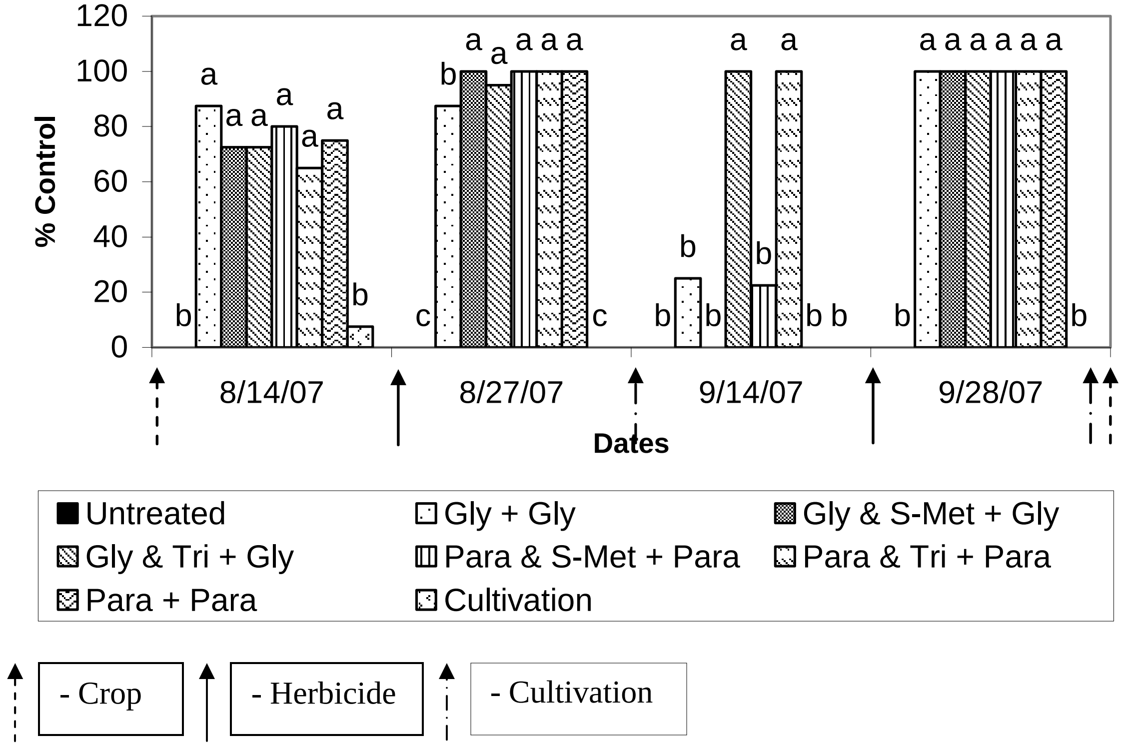


Figure 2-41. Effect of different fallow treatments on the control of cutleaf ground cherry plants during the second fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

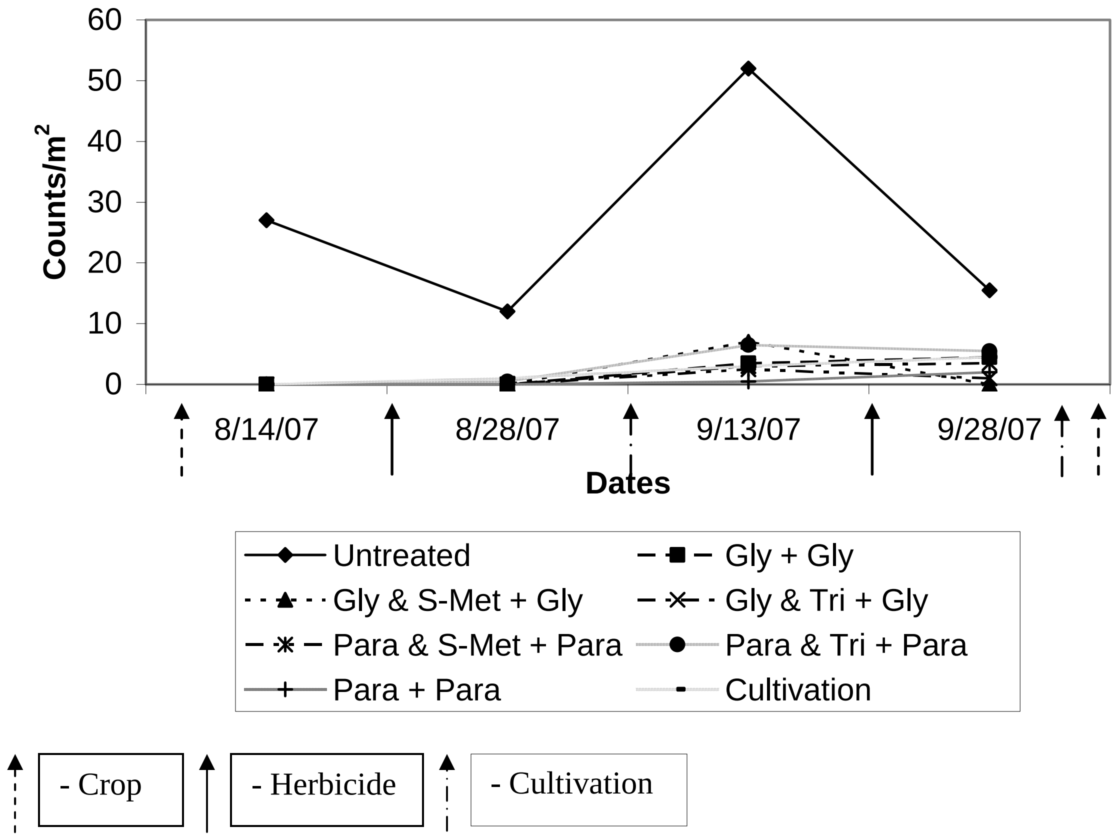


Figure 2-42. Effect of different fallow treatments on the population density of cutleaf ground cherry during the second fallow season in Citra, Fl. Weed counts include all living plants independent of visual health. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

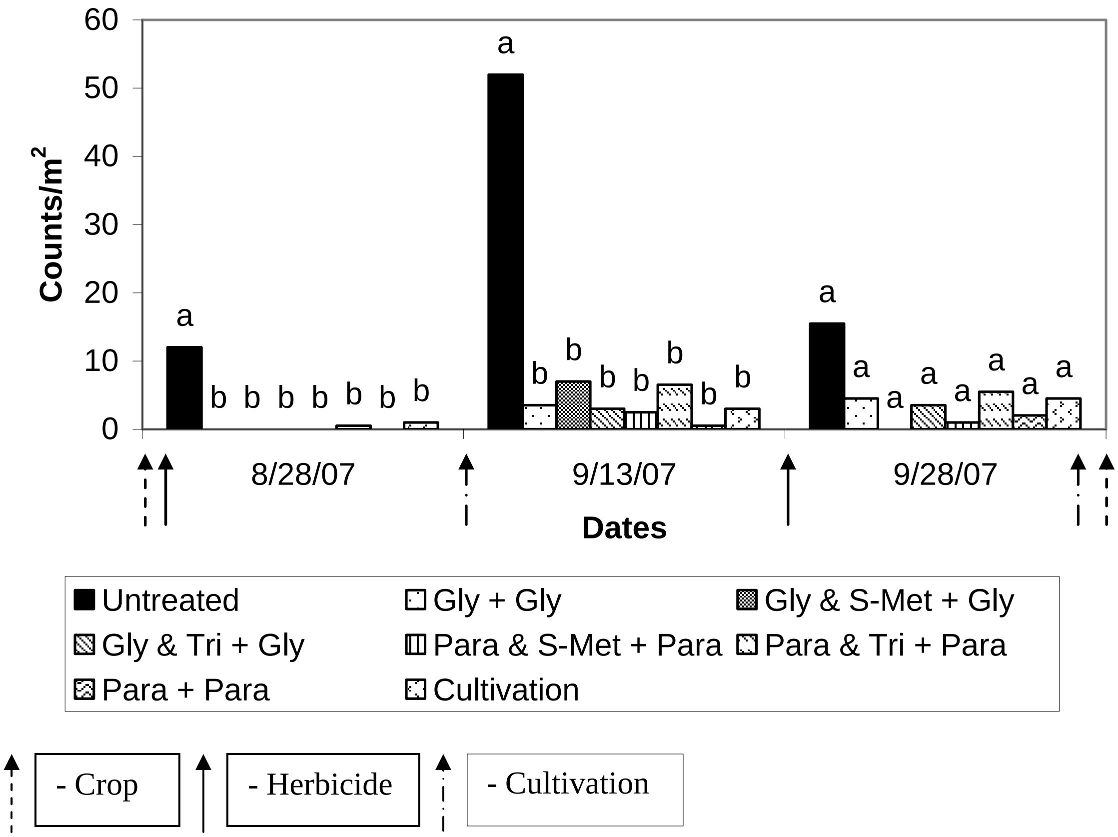


Figure 2-43. Effect of different fallow treatments on the population density of cutleaf ground cherry during the second fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

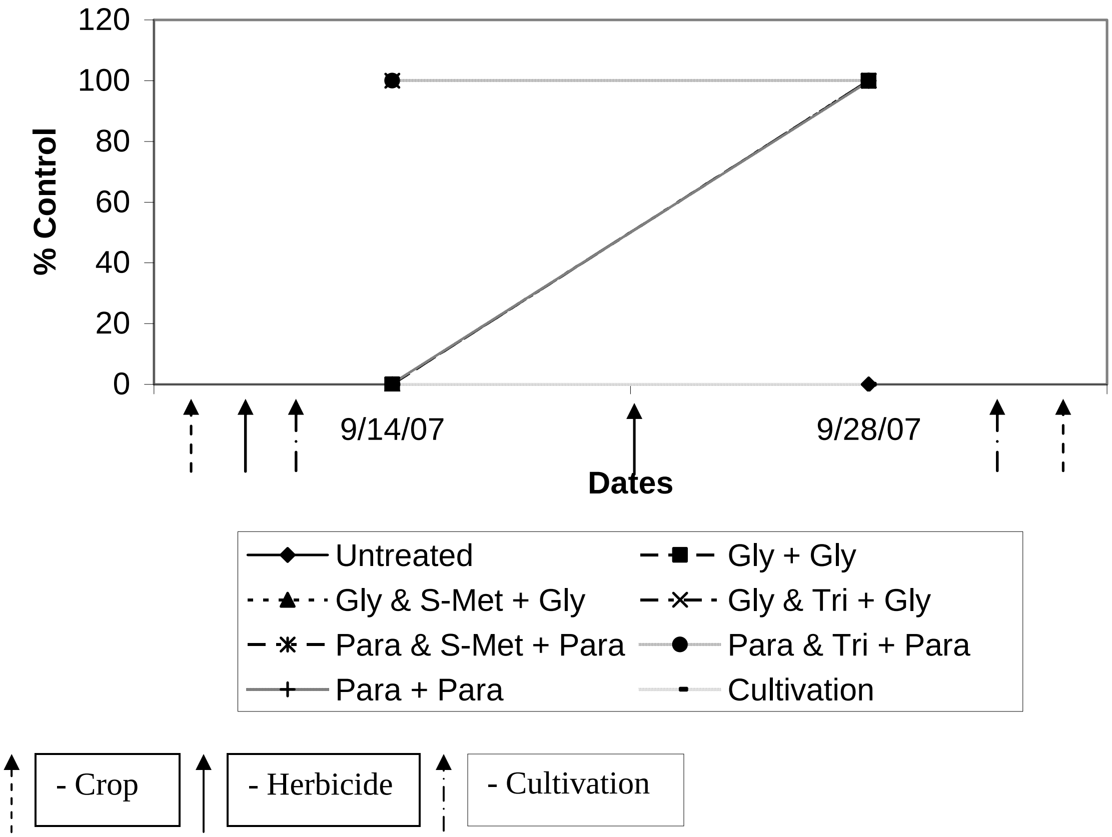


Figure 2-44. Effect of different fallow treatments on the control of carpetweed plants during the second fallow season in Citra, Fl. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

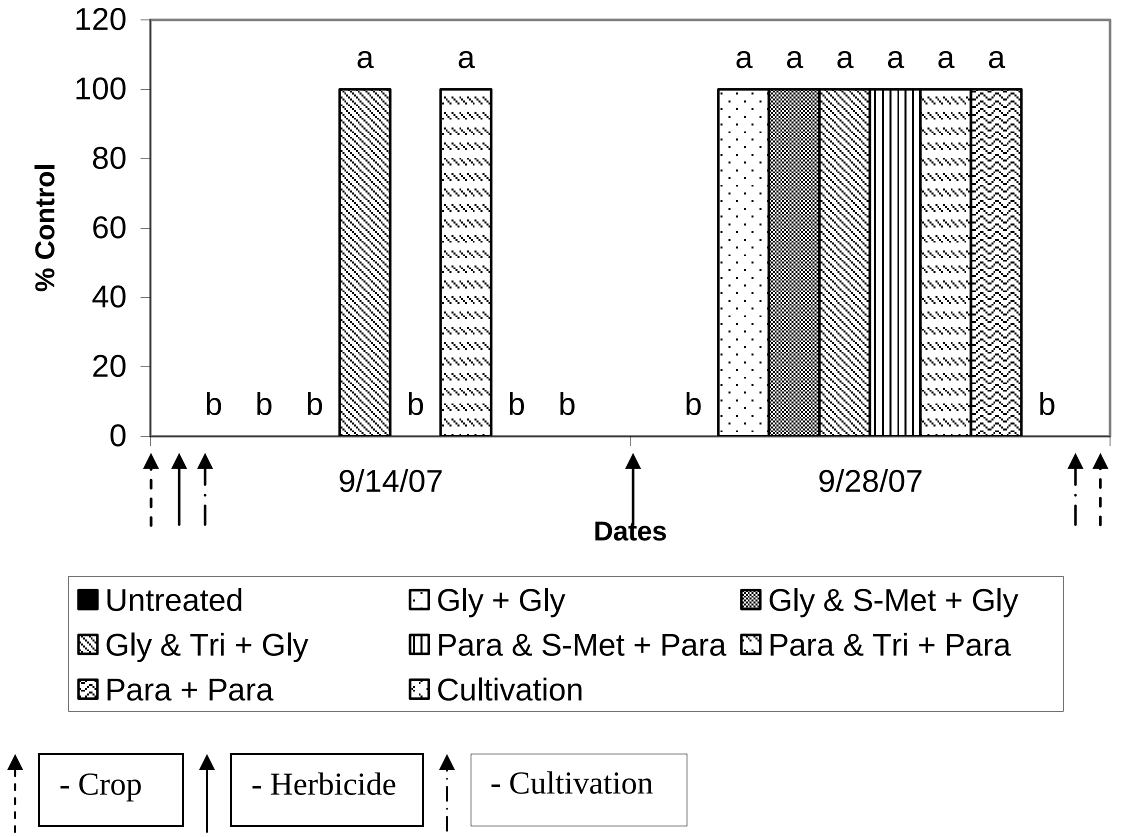


Figure 2-45. Effect of different fallow treatments on the control of carpetweed plants during the second fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

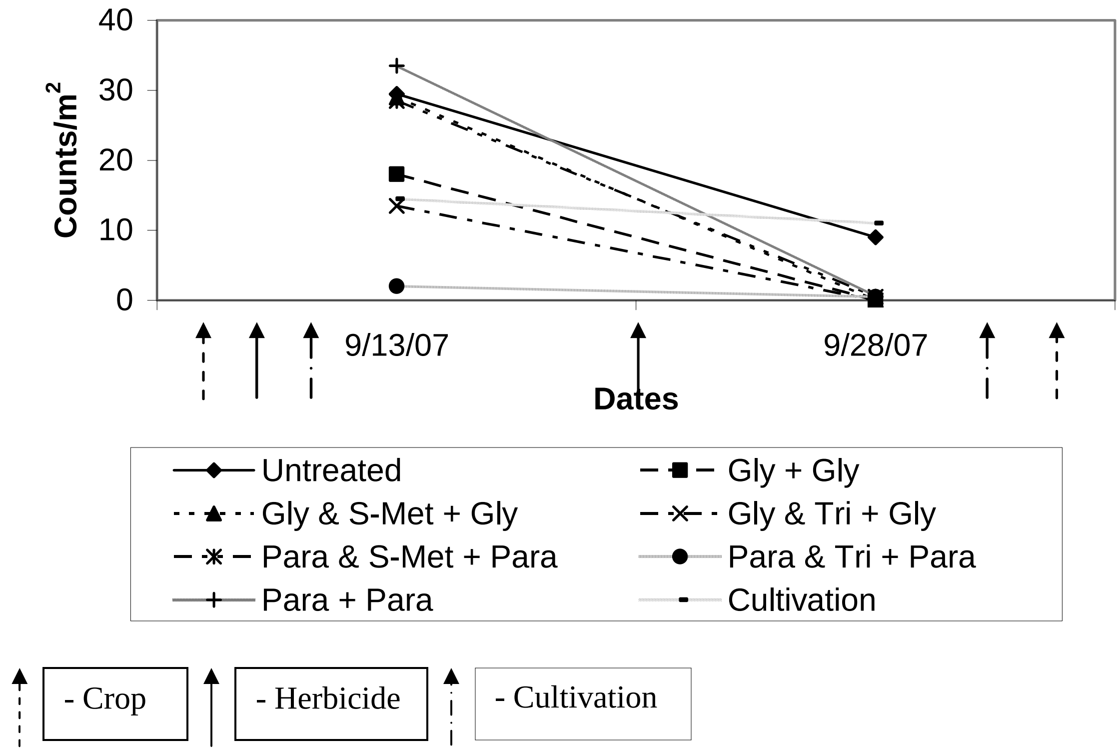


Figure 2-46. Effect of different fallow treatments on the population density of carpetweed during the second fallow season in Citra, Fl. Weed counts include all living plants independent of visual health. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

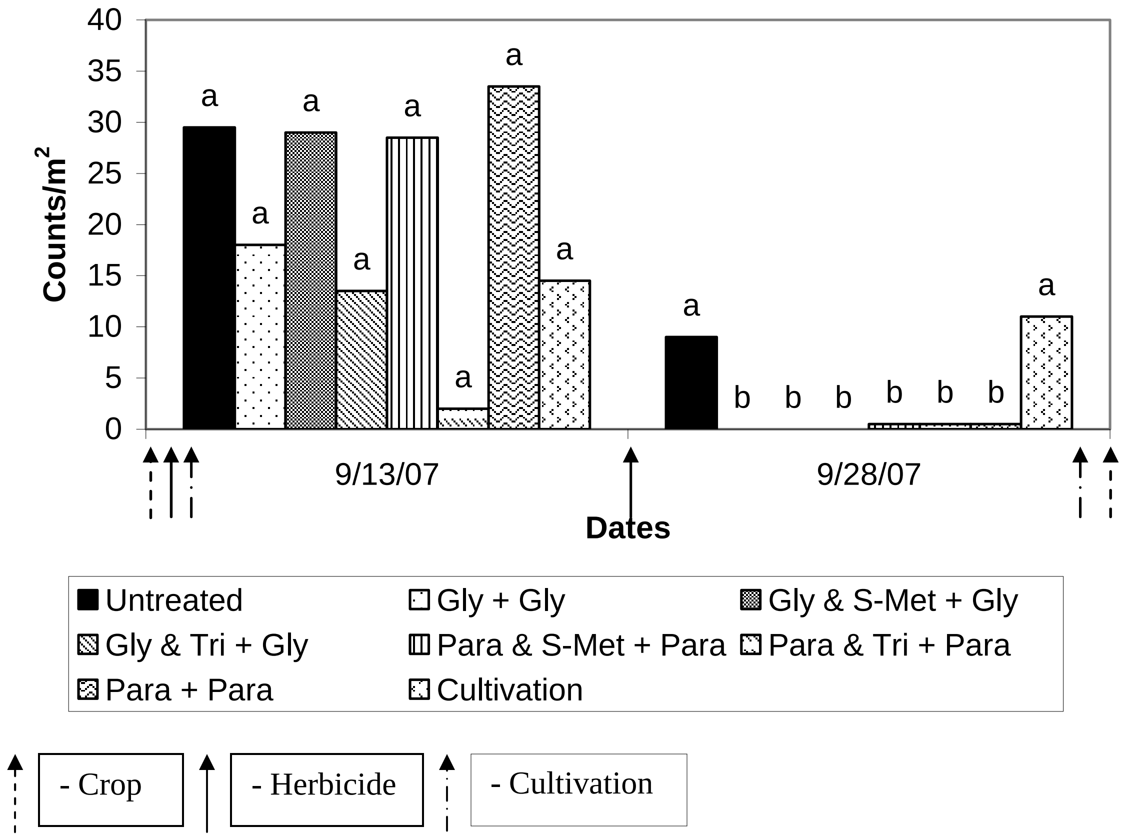


Figure 2-47. Effect of different fallow treatments on the population density of carpetweed during the second fallow season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Weed counts include all living plants independent of visual health. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

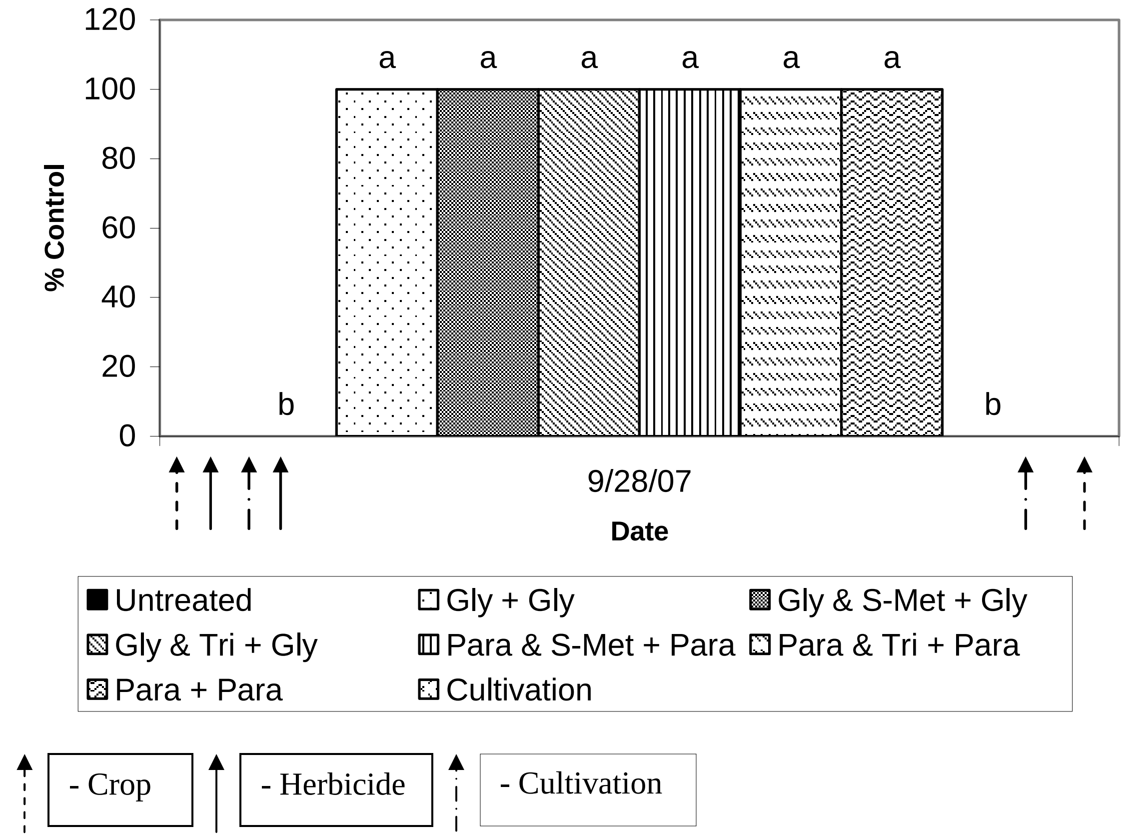


Figure 2-48. Effect of different fallow treatments on the control of redweed plants during the second fallow season in Citra, Fl. Means followed by the same letter not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop. Note x axis dates and treatment applications timelines are not drawn to scale.

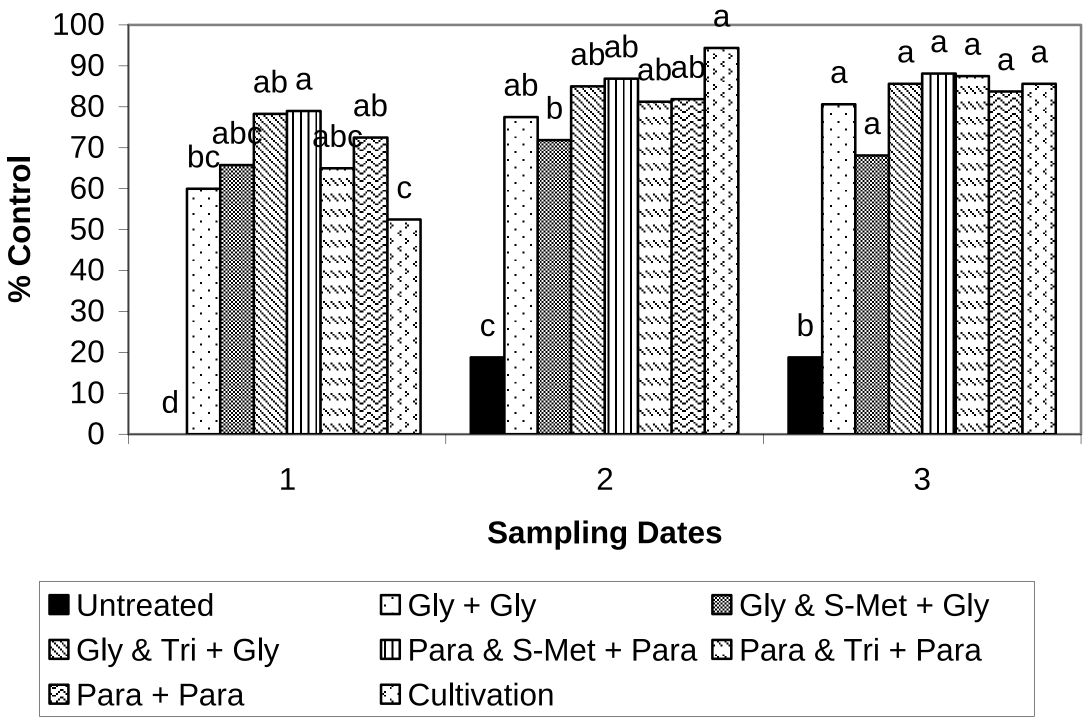


Figure 2-49. Effect of different fallow treatments on the control of purple nutsedge plants during the second crop season (cabbage) in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop.

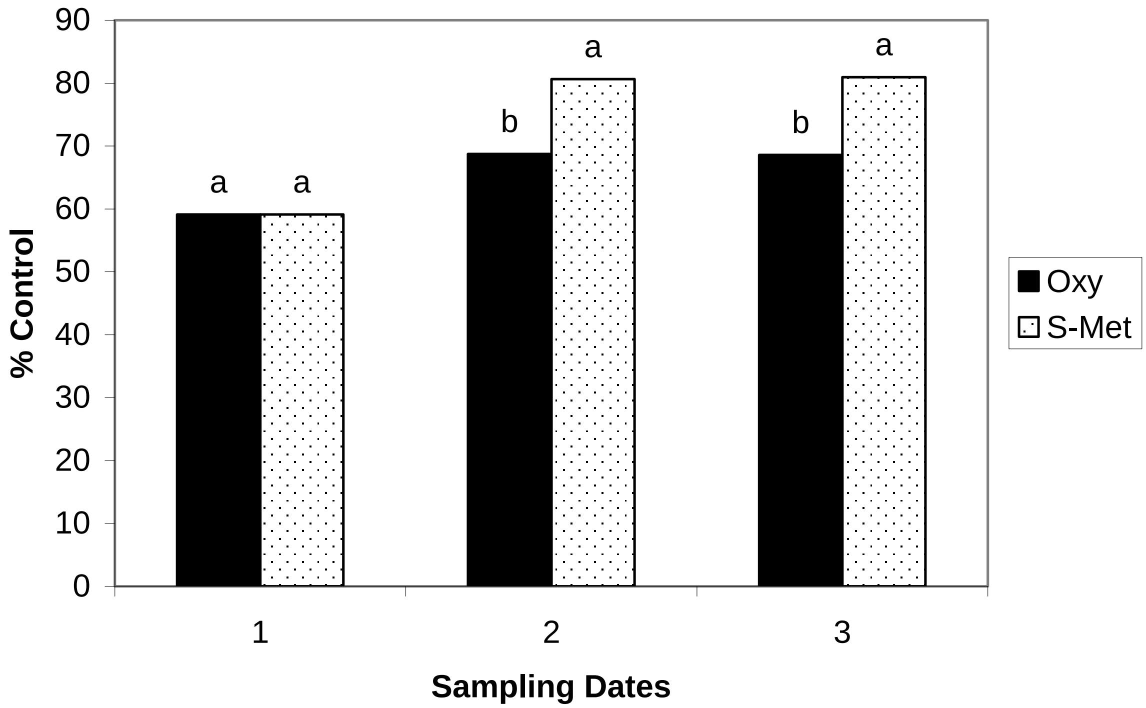


Figure 2-50. Effect of different pre-plant herbicide treatments on the control of purple nutsedge plants during the second crop season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

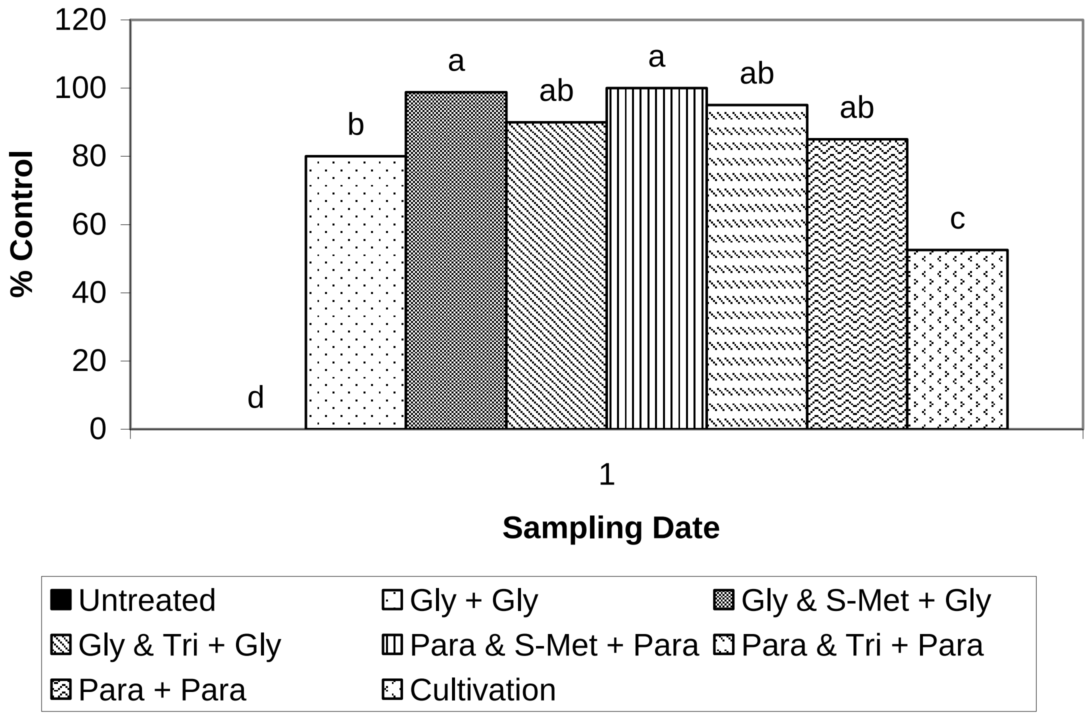


Figure 2-51. Effect of different fallow treatments on the control of yellow nutsedge plants during the second crop season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop.

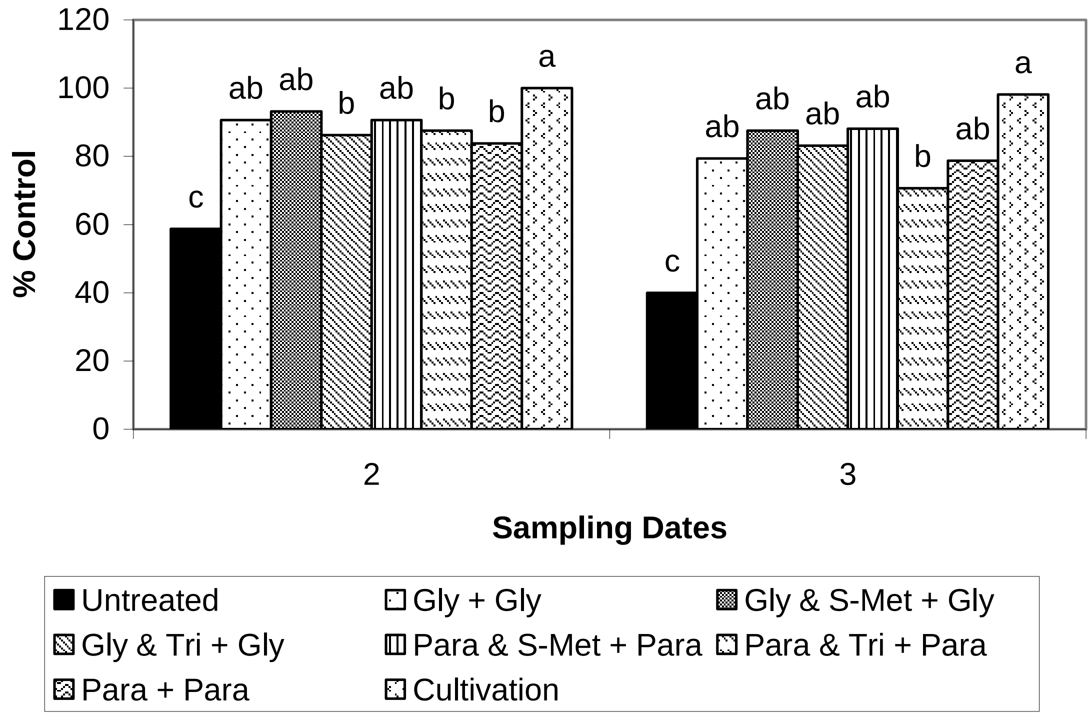


Figure 2-52. Effect of different fallow treatments on the control of crabgrass plants during the second crop season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop.

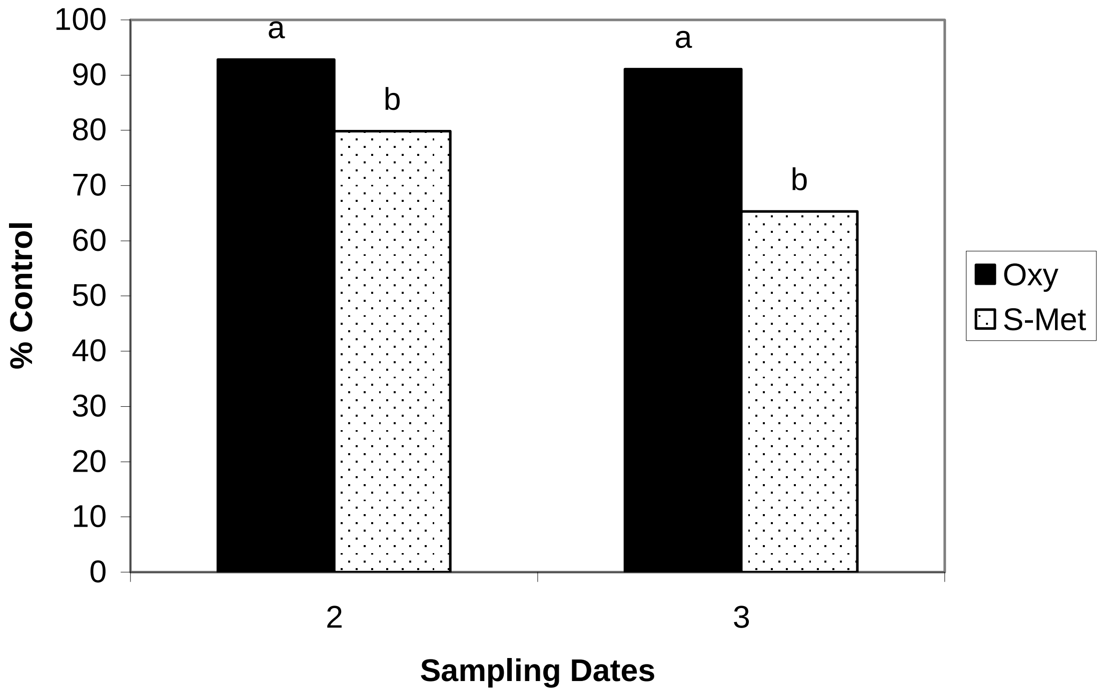


Figure 2-53. Effect of different pre-plant herbicide treatments on the control of crabgrass plants during the second crop season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

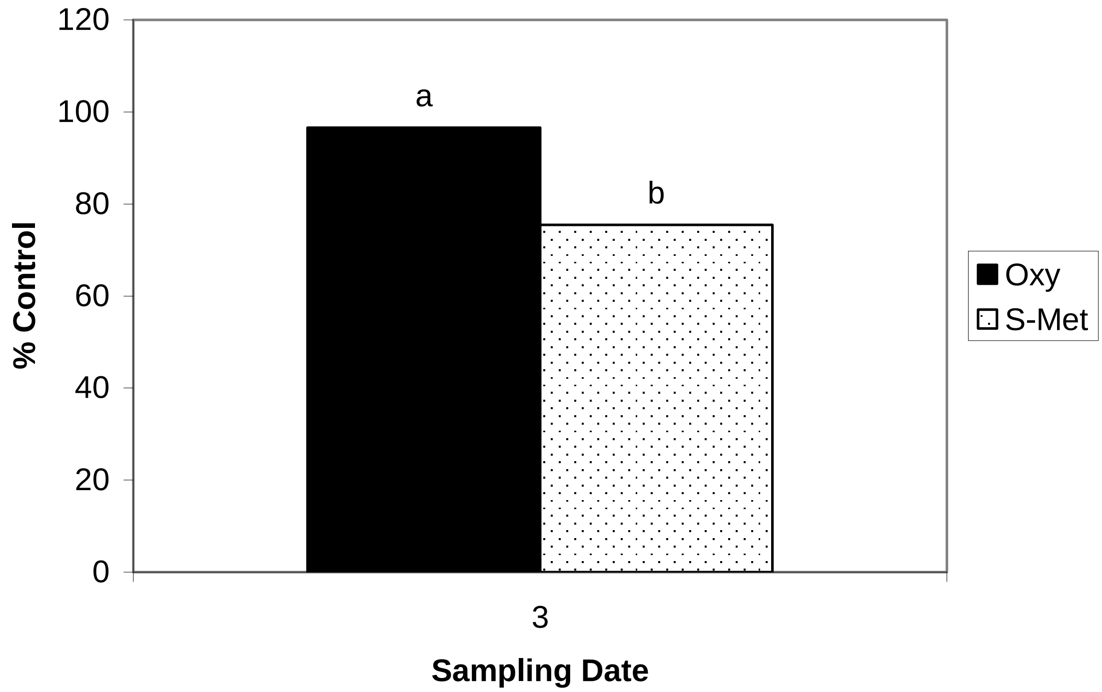


Figure 2-54. Effect of different pre-plant herbicide treatments on the control of cutleaf evening primrose plants during the second crop season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

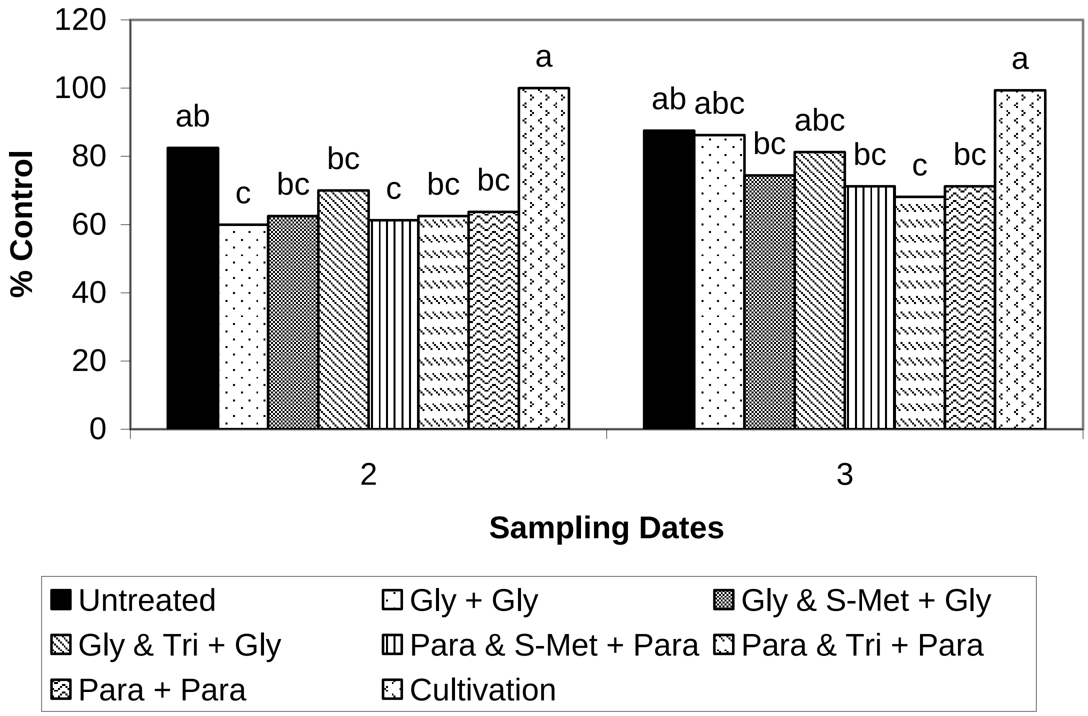


Figure 2-55. Effect of different fallow treatments on the control of purslane plants during the second crop season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop.

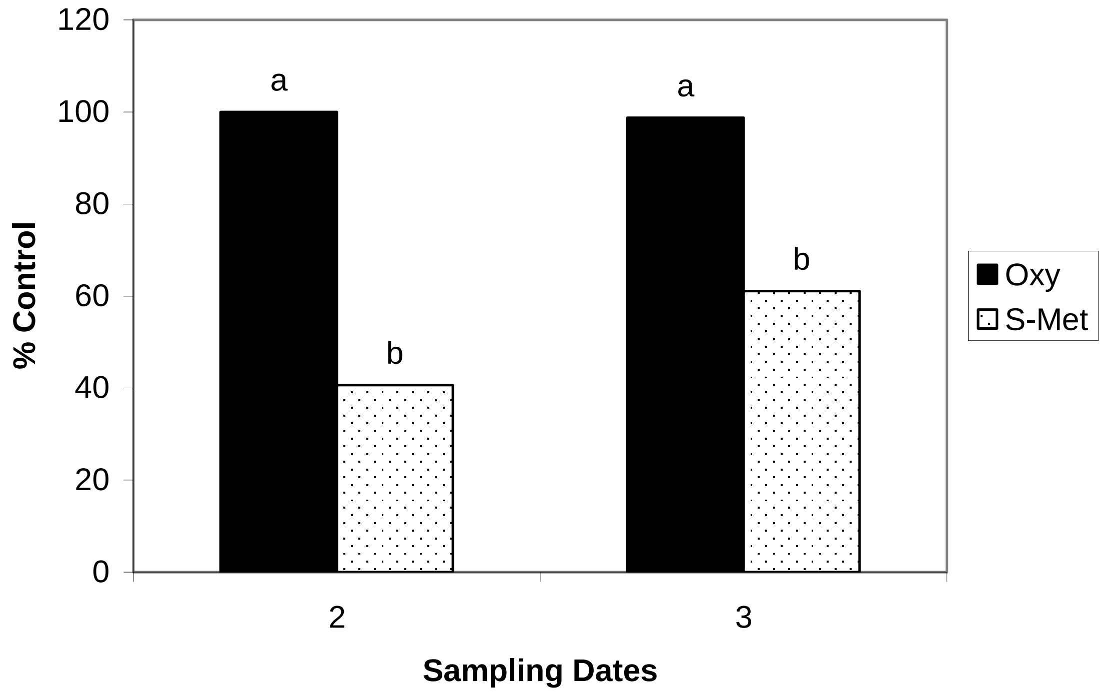


Figure 2-56. Effect of different pre-plant herbicide treatments on the control of purslane plants during the second crop season in Citra, Fl. Means followed by the same letter within a sampling date are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

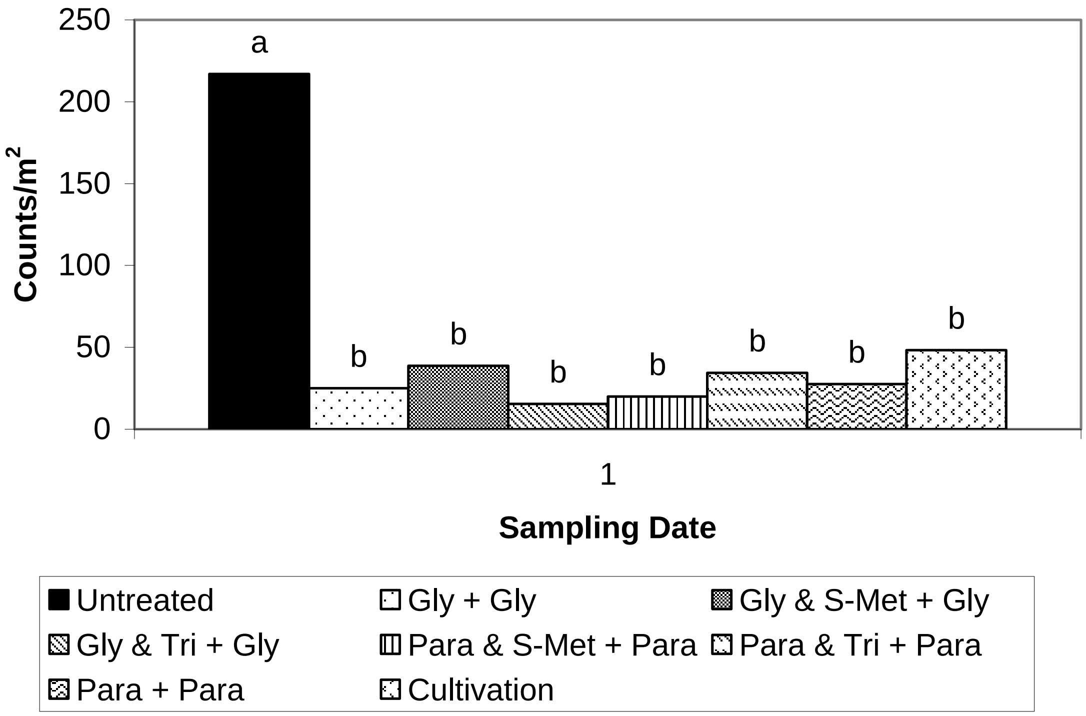


Figure 2-57. Effect of different fallow treatments on the population density of purple nutsedge plants during the second crop season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop.

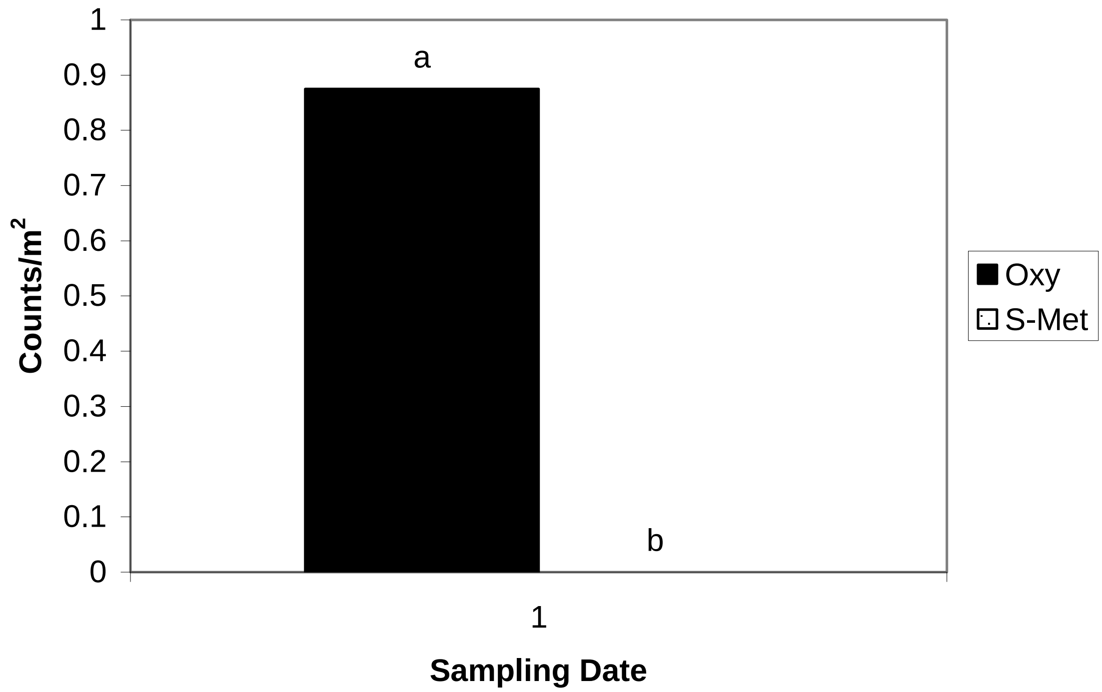


Figure 2-58. Effect of different pre-plant herbicide treatments on the population density of yellow nutsedge plants during the second crop season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

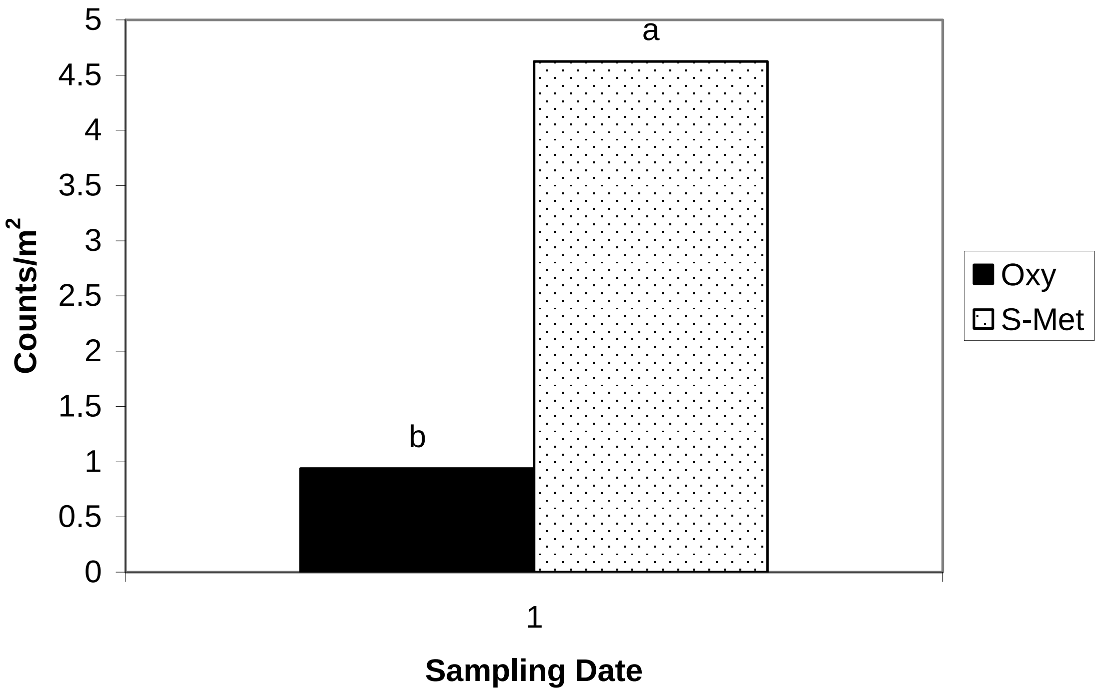


Figure 2-59. Effect of different pre-plant herbicide treatments on the population density of large crabgrass plants during the second crop season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death.

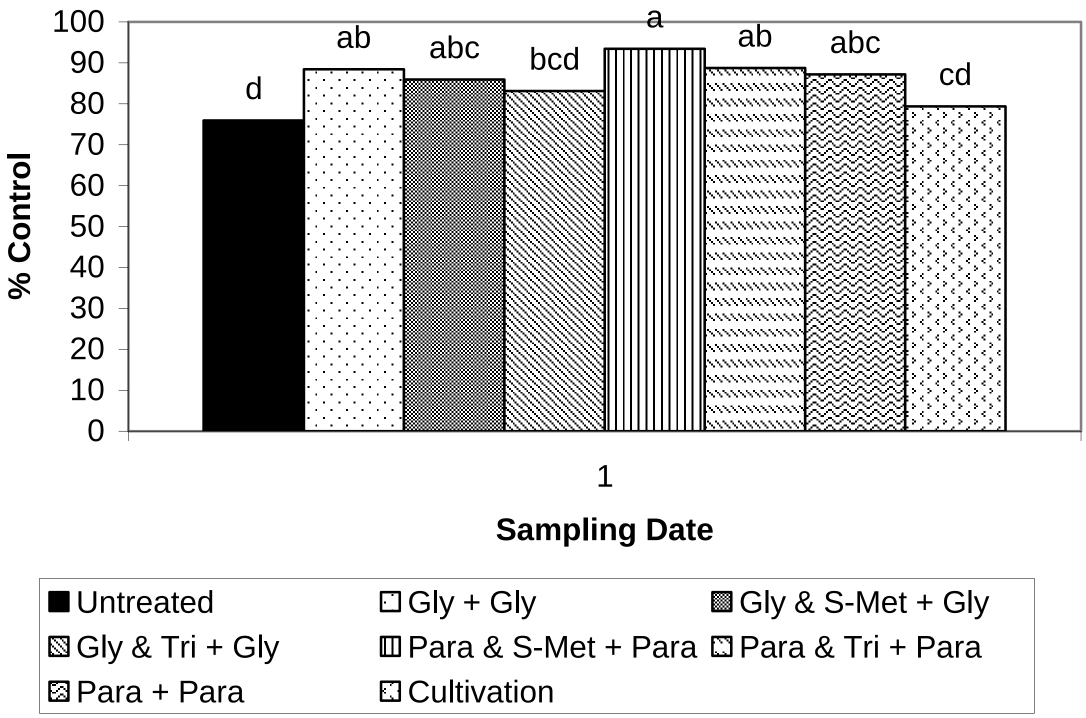


Figure 2-60. Effect of different fallow treatments on cabbage vigor during the second crop season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop.

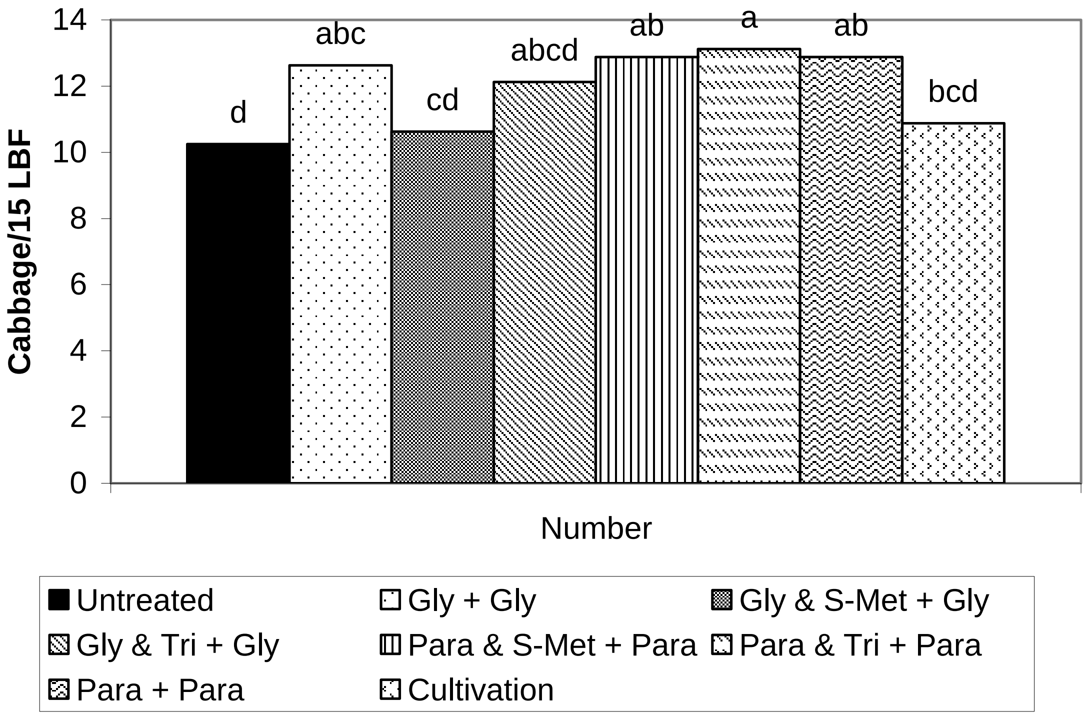


Figure 2-61. Effect of different fallow treatments on cabbage stand establishment during the second crop season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop.

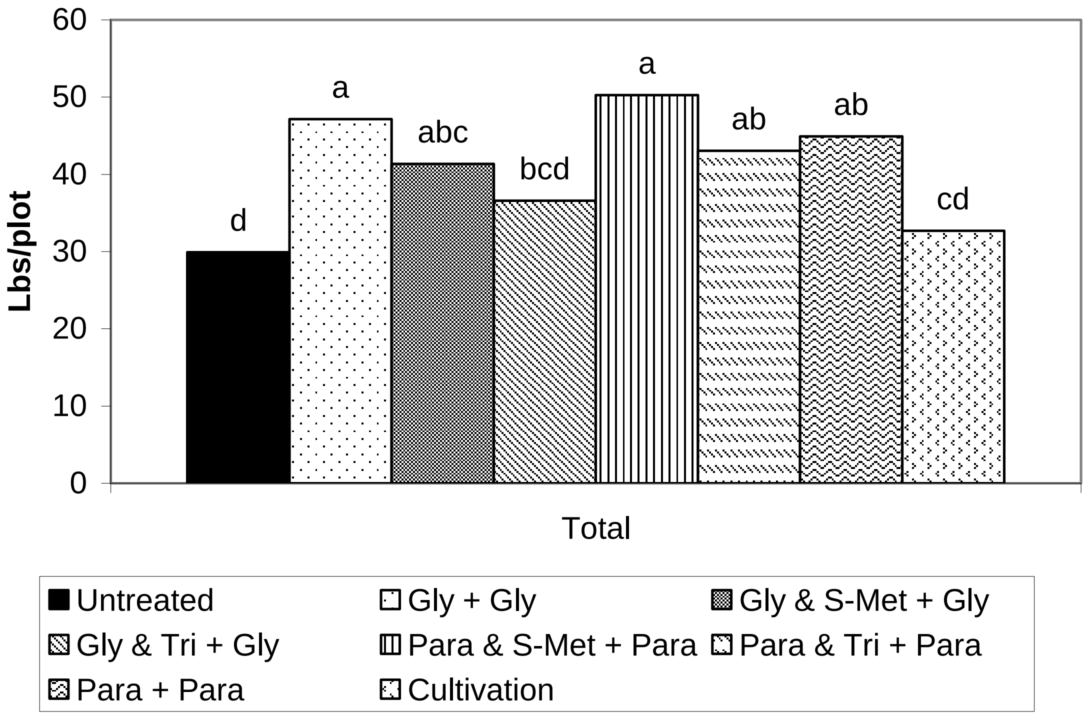


Figure 2-62. Effect of different fallow treatments on total cabbage weight per plot (15 LBF of row) during the second crop season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop.

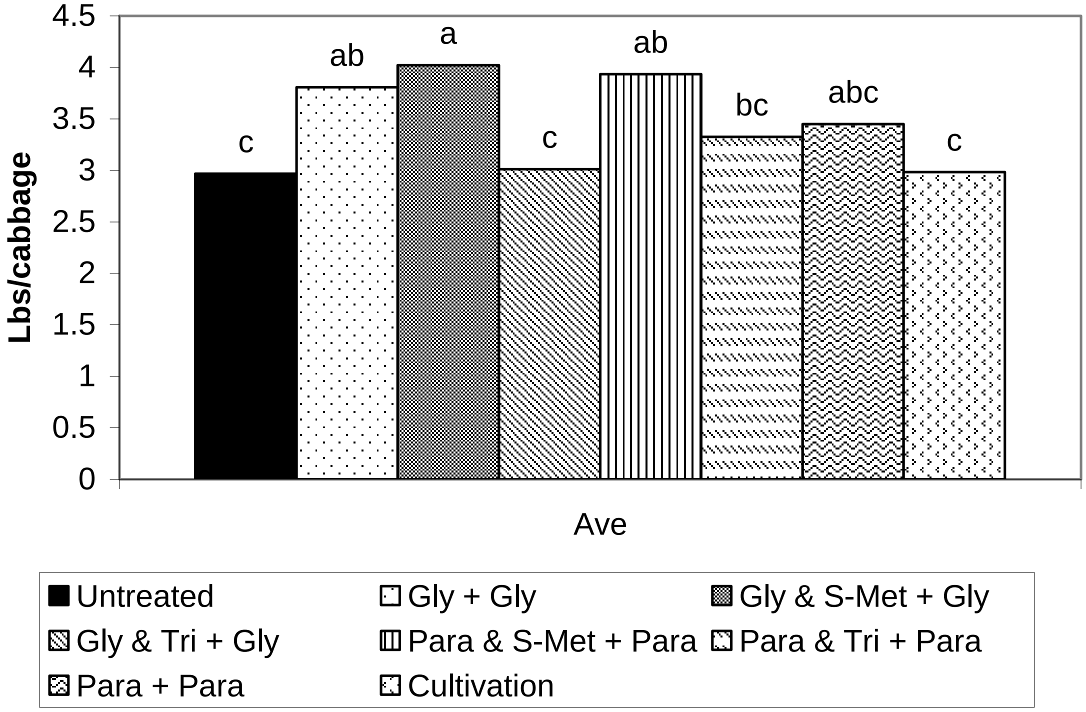


Figure 2-63. Effect of different fallow treatments on average cabbage weight during the second crop season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop.

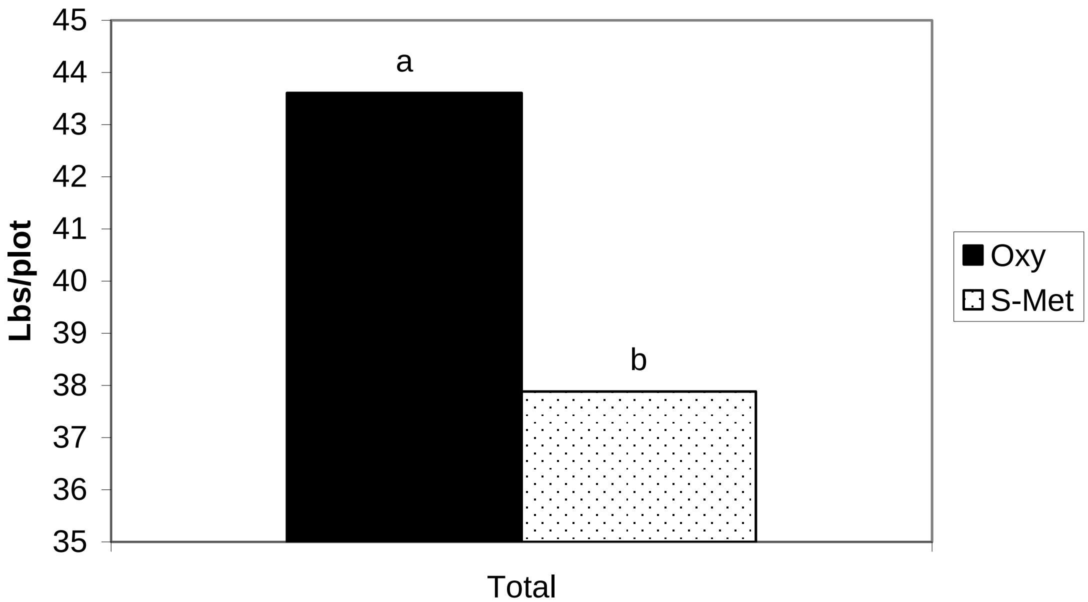


Figure 2-64. Effect of different pre-plant herbicide treatments on total cabbage weight per plot (15 LBF of row) during the second crop season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at $P = 0.05$.

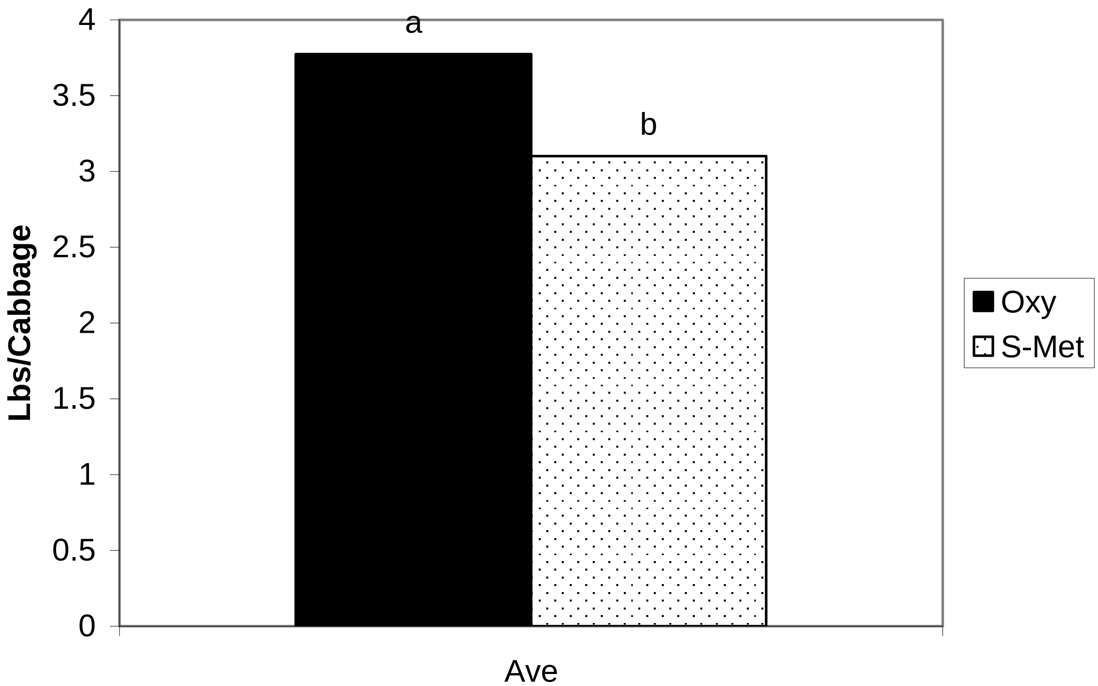


Figure 2-65. Effect of different pre-plant herbicide treatments on average cabbage weight per plot (15 LBF of row) during the second crop season in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05.

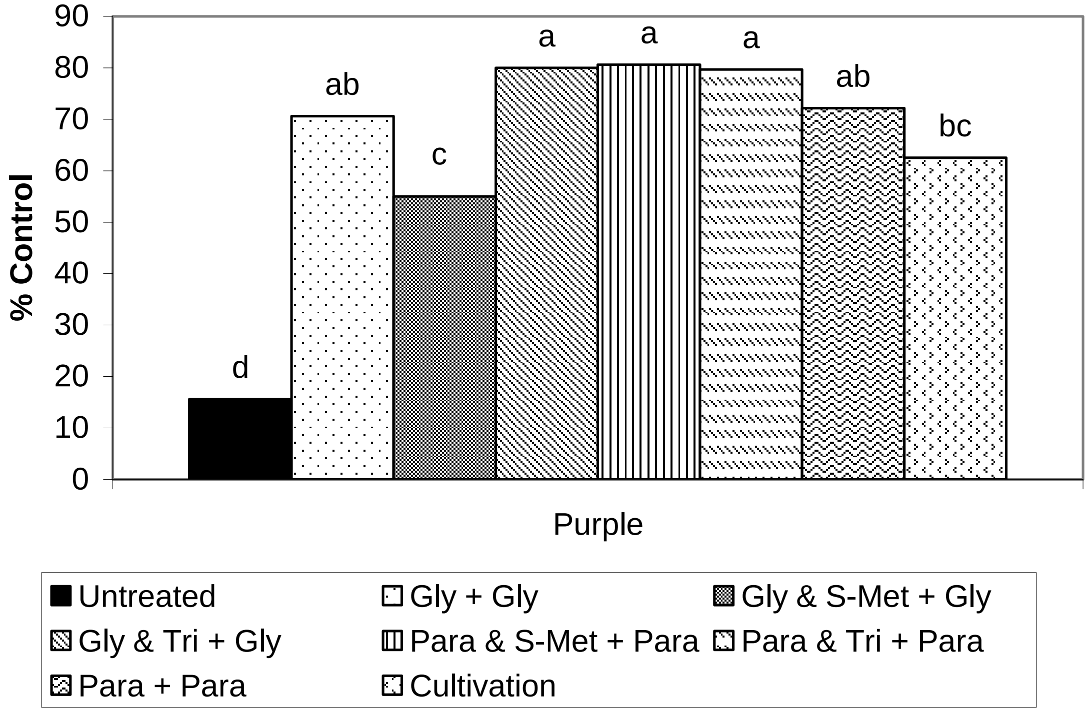


Figure 2-66. Effect of different summer fallow treatments on the long term control of purple nutsedge after the harvest of the second crop in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop.

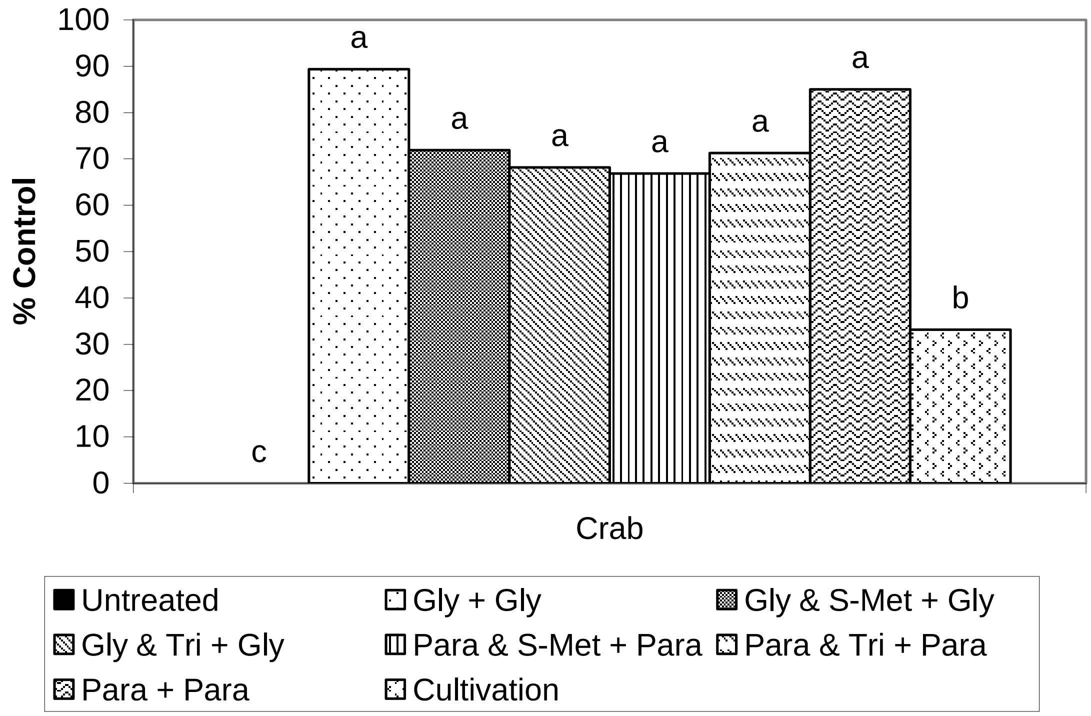


Figure 2-67. Effect of different summer fallow treatments on the long term control of large crabgrass after the harvest of the second crop in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop.

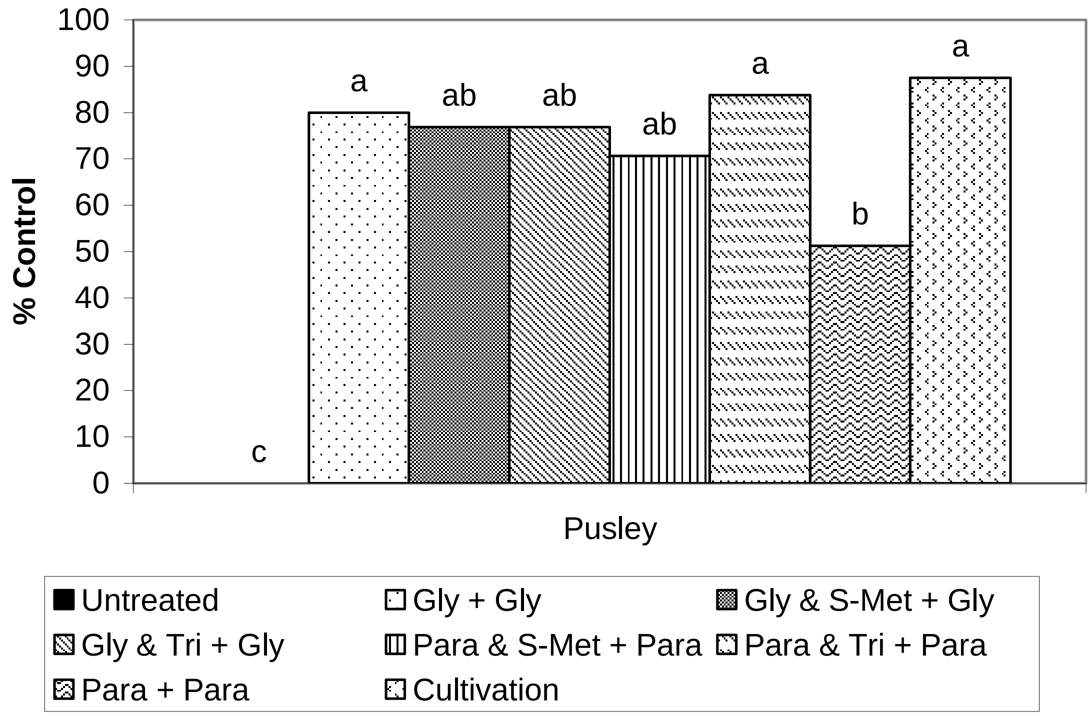


Figure 2-68. Effect of different summer fallow treatments on the long term control of Florida pusley after the harvest of the second crop in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop.

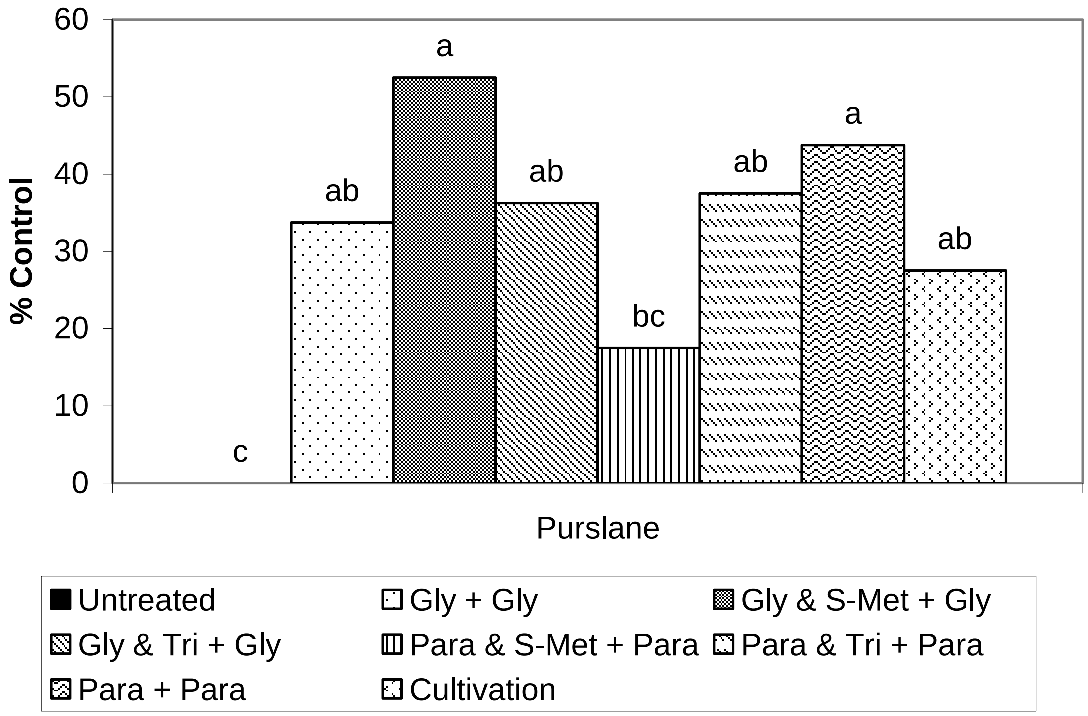


Figure 2-69. Effect of different summer fallow treatments on the long term control of common purslane after the harvest of the second crop in Citra, Fl. Means followed by the same letter are not significantly different according to Fisher's Least Significant Difference test at P = 0.05. Control is defined as plant chlorosis, necrosis, stunting, or death. Cultivation was performed to all treatments plots during the fallow period, however, hand hoeing was implemented to the cultivation treatment on a biweekly basis in the second crop.

CHAPTER 4
CONCLUSIONS – LIVE OAK AND CITRA SUMMARY

Untreated Fallow Effect on Weeds

In general, fallow fields left unattended between production cycles resulted in higher weed infestation compared to all other treatments. These results were observed for yellow nutsedge, Florida pusley and large crabgrass in Live Oak. In Citra, this pattern was continued for all weeds observed during the fallow period.

Live Oak

Purple nutsedge and carpetweed counts in untreated plots were lower than the cultivated check in Live Oak. The untreated check contained less purple nutsedge than the cultivated check, but the herbicide treated plots contained the least amount of nutsedge. A possible explanation is cultivation may have caused dormant tubers to sprout by breaking apical dominance in purple nutsedge tuber chains. In addition, cultivation may cause a shift in species due to lower competition from more vigorous weed species and allow nutsedge a chance to proliferate.

Carpetweed counts were lower in the untreated plots compared to the cultivated check and glyphosate plus cultivation after cultivation was implemented. Carpetweed is a pioneer rudimentary species that may take advantage of soil disturbance, which may explain why cultivation increases carpetweed numbers compared to the untreated check.

Citra

All the weeds were higher in the untreated plots compared to the cultivated check in Citra, except purslane. The untreated check contained less purslane than the cultivated check. Similar to carpetweed, purslane is a weed species that colonizes disturbed areas, which may account for the increased numbers in the cultivated checks.

Effect of Fallow Cultivation on Weeds (Regardless of Herbicides) - Live Oak

Cultivation may cause an increase flush of seedlings when it is initially implemented. However, the effect of multiple cultivation events over a two year period generally decreases the amount of weeds in the field regardless of herbicide applications. The effect of cultivation on pusley counts varied overtime. Initially cultivation caused an increase in the pusley population. This increase in seedling emergence was probably due to the soil disturbance which released the seeds from dormancy and caused sprouting. However, by the beginning of the second fallow season, cultivated plots had less pusley than non-cultivated plots. Multiple sequential tillage events seemed to deplete the soil seed reserves and prevent plants from maturing to seed production capacity.

Fallow Cultivation Effect on Weeds

In general, cultivation alone resulted in lower weed counts than the untreated check and higher weed counts than the treatments that contained herbicides for most weed species. This was the case observed for Florida pusley and crabgrass (depending when cultivation was implemented) in Live Oak. In Citra, this trend was observed during the first year for purple nutsedge, crabgrass, amaranth, purslane, Florida pusley, and cutleaf eveningprimrose. During the second year this trend was observed for purple nutsedge and cutleaf ground cherry counts.

However, there were some weeds that did not follow this general pattern. During the fallow period the cultivated check contained the highest number of purple nutsedge compared to all other treatment plots in Live Oak. Cultivation provided similar yellow nutsedge control as the herbicide treatments, which was better than the untreated check. Cultivation and cultivation plus glyphosate resulted in the highest number of carpetweed after cultivation was implemented. In Citra, cultivation did not increase the control of yellow nutsedge for both years of the study, but crabgrass, amaranth, Florida pusley, and carpetweed were controlled during the second year only. Purslane was the only weed species in which counts were higher in the cultivated plots than in the untreated check during the second year.

Cultivation controlled the weeds that were present well (in many cases as well as herbicides), however it did not prevent the re-establishment of many of these weeds. Overall, cultivation resulted in similar weed control at both locations with the exception of a few weed species. Most notably, cultivation had the opposite effect on purple nutsedge during the fallowing period compared to Live Oak.

Effect of Fallow Herbicides on Weeds (Regardless of Cultivation) - Live Oak

In general herbicide treatments provided better weed control than non-herbicide treated plots. In addition, there usually was no difference between weed counts in glyphosate and glyphosate plus halosulfuron treated plots. Glyphosate and glyphosate plus halosulfuron treatments provided better weed control than non-herbicide treatments for several weeds including, pusley and hairy indigo. Glyphosate treatments controlled smallflower morningglory better than non-herbicide treatments. There were no differences in weed control efficacy between glyphosate and glyphosate mixed with halosulfuron for any weeds.

Fallow Herbicide Effects on Weeds

In general, herbicides provided better weed control than the untreated check and in many cases outperformed cultivation. This was the trend observed for purple nutsedge and Florida pusley in Live Oak. However, yellow nutsedge and carpetweed did not follow this pattern. Yellow nutsedge levels in herbicide plots were comparable to the levels in the cultivated check plot, but lower than the levels in the untreated check. Directly after cultivating the glyphosate plus cultivation plot there was a significant increase in carpetweed compared to the uncultivated glyphosate plot in Live Oak.

Herbicides provided better weed control than the untreated check for most weed species following an herbicide application. Glyphosate provided excellent systemic post-emergent control of most weed species at both locations. Increased weed control was achieved with glyphosate when applied to actively growing plants in moist soils compared to drought stressed plants in dry soils. In addition, paraquat applications resulted in temporary burndown post emergent control of most weed species in Citra. Besides burndown control, paraquat provided complete weed control of many species when multiple applications were made in conjunction with tillage. All herbicides and herbicide combinations provided better yellow nutsedge control than paraquat during the second year of fallowing in Citra. Neither glyphosate nor paraquat provided pre emergent control or residual control of weeds. Adding trifloxysulfuron or s-metolachlor to glyphosate or paraquat often improved post-emergent control and provided pre emergent control of weeds.

Sulfonylurea herbicides did not perform similarly at both locations. There usually was not any difference in weed counts between glyphosate and glyphosate plus halosulfuron in Live Oak. At Live Oak, glyphosate provided excellent weed control by itself and the addition of halosulfuron did not provide any incremental control. Ideal weather conditions may have lead to the high level of control provided by glyphosate. Under suboptimal conditions halosulfuron may have improved weed control. Adding trifloxysulfuron to glyphosate or paraquat improved post-emergent control of purple nutsedge and pre-emergent control of most broadleaf weeds in Citra. This pattern was observed for amaranth, purslane, Florida pusley, cutleaf ground cherry and carpetweed.

There were increased purple nutsedge counts in the glyphosate tank-mixed with s-metolachlor treated plots compared to the glyphosate plus trifloxysulfuron plots during the second year. No differences in purple nutsedge control between glyphosate and paraquat were observed either year. An increase in weed control was observed for yellow nutsedge and crabgrass and other grass species when adding s-metolachlor to glyphosate or paraquat.

At the Live Oak location, cultivation practice typically did not affect weed counts in herbicide treated areas. All herbicides and herbicide combinations performed equally for the following weeds: crabgrass and Florida pusley during the first year and yellow nutsedge during the second year (counts) in Citra. Many times all herbicide combinations killed the weeds present at the time of application but did not provide any residual control, except for trifloxysulfuron. All post-emergent herbicides performed better when applied to small, tender, succulent, more susceptible weeds. All herbicides performed better under conditions that stimulated weed growth, such as warm temperatures and optimal soil moistures.

Effect of Fallow Treatments on Weeds within Peppers

Untreated Fallow Effect on Peppers - Live Oak

The untreated check resulted in lower purple nutsedge counts than the cultivated check, but not lower than the herbicide treatments during year one. During year two, the untreated check had the highest amount of purple nutsedge within the pepper row compared to all the other fallow treatments.

Fallow Cultivation Effect on Peppers - Live Oak

Fallow cultivation plots contained the greatest amount of purple nutsedge during the first pepper crop. Cultivation during the fallow period resulted lower purple nutsedge counts than the untreated control, but higher nutsedge counts than the herbicide treated plots during the second pepper crop.

Effect of Fallow Herbicides on Bell Pepper (Regardless of Cultivation) - Live Oak

Glyphosate and glyphosate tank-mixed with halosulfuron increased Florida pusley control within both pepper rows and row middles. In addition, crabgrass row middle control was increased by glyphosate and glyphosate plus halosulfuron. Peppers were taller in the non-herbicide plots compared to both herbicide treatments.

Fallow Herbicide Effect on Peppers - Live Oak

Herbicide treatments did not lower purple nutsedge counts more than the untreated check, but did lower purple nutsedge counts more than the cultivated check. In the second pepper crop, herbicides reduced purple nutsedge numbers more than the cultivated and untreated check plots. There was no difference in purple nutsedge control between glyphosate and glyphosate tank-mixed with halosulfuron, with or without cultivation.

Effects of Fallow Treatments on Snap Beans

Effect of Fallow Cultivation in Snap Beans (Regardless of Herbicides) - Live Oak

Fallow cultivation prior to planting decreased the crabgrass presence during the first cropping season in snap beans.

Effect of Fallow Herbicides on Snap Beans (Regardless of Tillage) - Live Oak

Percent weed cover of all weed species combined, Florida pusley, and crabgrass numbers were decreased by glyphosate and glyphosate plus halosulfuron during the first year. Glyphosate tank-mixed with halosulfuron controlled smallflower morningglory better than non-herbicide treatments in bean rows during the second year. Purple nutsedge was controlled better by glyphosate and glyphosate tank mixed with halosulfuron compared to non-herbicide plots both years of the study. There were no differences in weed control between glyphosate and glyphosate plus halosulfuron treatments for any of these weeds.

Effect of Fallow Treatments on Weeds within Cabbage

Untreated Fallow Effect on Cabbage

The untreated check resulted in the lowest level of purple nutsedge compared to all the other treatments in cabbage during the second cropping season. There were no significant differences in cabbage yields between fallow treatments in Live Oak. The weed species that were present during the summer fallow were killed by frost or in a dormant stage during the winter cabbage crop in Live Oak. The only weeds that were present were winter annuals. Therefore there was not much weed competition from weeds controlled by fallow treatments.

The Citra location was much warmer during the winter compared to the Live Oak location. Thus summer annuals were not killed by the frost and perennials did not go dormant. There was more competition from summer weed population in Citra compared to Live Oak due to the warmer weather. The untreated control typically resulted in the lowest weed control, the highest weed counts, the lowest cabbage vigor and yields. Purslane infestation was less in the untreated plots compared to the other treatments. The untreated control provided similar weed control and cabbage yields as many of the other treatments in Citra.

Fallow Cultivation Effect on Cabbage

Cultivation during the fallow period resulted in a higher level of purple nutsedge control than the untreated check, but provided less control than the herbicide treatments in Live Oak. Tillage killed purple nutsedge shoots and depleted tuber carbohydrate reserves over a long period of time. Biweekly hand hoeing during the cropping season resulted in higher weed control than the untreated check, but did not improve cabbage vigor or yield in Citra. In addition, hand hoeing provided weed control comparable to the best herbicide treatments for purple nutsedge and crabgrass. Yellow nutsedge control was higher in the cultivated check compared to the untreated check, but was lower than the control provided by herbicides in Citra. However, yellow nutsedge was non existent in most plots after the second hand hoeing, therefore data was not collected. Purslane control was similar between the best herbicide treatments, the cultivated check, and the untreated check.

Fallow Herbicide Effect on Cabbage - Live Oak

Treatments that contained herbicides, glyphosate and glyphosate tank-mixed with halosulfuron, provided the highest level of purple nutsedge control. There was no difference in purple nutsedge control between glyphosate and glyphosate tank-mixed with halosulfuron, with or without cultivation.

Fallow Herbicide Treatment Effect on Weeds during Cabbage Crop - Citra

Weed control was highest in the herbicide treated plots. Herbicides applied during the fallow often provided the same level of weed control as hand hoeing every other week (cultivated check) during the crop. This was observed in all weeds on all sample dates except for purple nutsedge, yellow nutsedge and purslane on the first sample date.

Many times the different fallow herbicides resulted in similar weed control during the cropping season for crabgrass and purslane. Sometimes the fallow herbicide treatments provided variable control depending on the weed species for purple and yellow nutsedge. At the beginning of the crop paraquat plus s-metolachlor controlled purple nutsedge better than glyphosate alone. S-metolachlor mixed with either glyphosate or paraquat provided better yellow nutsedge control than glyphosate by itself.

Fallow Treatment Effect on Cabbage Vigor and Yield - Citra

Overall, the untreated check and the cultivated check consistently resulted in the poorest cabbage stand establishment, size, vigor, and yield. In addition, it appears trifloxysulfuron negatively affected cabbage size, vigor, and yield.

The untreated check, the cultivated check and the plots treated with glyphosate plus trifloxysulfuron had the lowest cabbage vigor and yields. All the other fallow herbicide plots resulted in the highest cabbage vigor. Trifloxysulfuron tank-mixed with either glyphosate or paraquat, the untreated check, and the cultivated check yielded the smallest cabbage size per head. The untreated check, the cultivated check and the plots treated with glyphosate tank-mixed with s-metolachlor during the fallow period had the lowest stand establishment. All the other fallow herbicide, except those herbicide treatments with trifloxysulfuron, had higher cabbage yield and size.

Effect of Pre-plant Herbicides on Cabbage

In regards to pre-plant herbicides, oxyfluorfen provided the best weed control and highest yields compared to s-metolachlor and the untreated subplots for most weed species in Live Oak. Furthermore, s-metolachlor did not control weeds as well as oxyfluorfen but provided better control than the untreated subplots in general. In Citra, s-metolachlor provided greater control of purple and yellow nutsedges, but not to the extent as fallow herbicide treatments. Oxyfluorfen provided superior control of grasses and broadleaf weeds. In addition, oxyfluorfen resulted in greater cabbage size and total yield when compared to s-metolachlor in Citra. Crabgrass was controlled better by oxyfluorfen compared to s-metolachlor. Oxyfluorfen provided a higher level of cutleaf evening primrose and purslane compared to s-metolachlor.

Based upon the results of these studies, it is recommended to apply herbicides during the fallow period to control weeds. A sulfonylurea herbicide used in conjunction with glyphosate or paraquat to provide pre, post control and residual of broadleaves and sedges for non-sensitive crops. Sulfonylurea herbicides should not be used in sensitive crops such as cabbage. Adding s-metolachlor to glyphosate or paraquat will provide pre-plant control, not provided by glyphosate or paraquat alone. Both glyphosate and paraquat are recommended for weed control because they are inexpensive, provide good weed control, and do not negatively impact crop yields. It would be beneficial to implement herbicide fallow weed control to control perennial weeds such as purple and yellow nutsedge. Fallow weed control is very beneficial to control all weeds in minor vegetable crops that have no registered herbicides labeled for use in those crops. Herbicide fallow and cultivation decrease annual weed presence by limiting the seed rain deposited into the soil seed bank. Furthermore, cultivation depletes the soil seed bank by seed burial and seedling emergence. Cultivation would be useful for controlling annual weeds in organic production systems. Cultivation also controls nutsedges but not nearly as well as herbicide treatments, but is an option for those systems excluding herbicides from the weed management program. Based upon the results from this study, applying a pre-plant herbicide in addition to implementing fallow weed control measures is recommended to control annual weeds. Oxyfluorfen provides the best control of emerging grasses and broadleaves seedlings missed by fallow weed control.

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BIOGRAPHICAL SKETCH

Theodore (Teddy) Porter McAvoy was born in New Brunswick, New Jersey on in 1982. He was born to Eugene Joseph McAvoy and Donna Marie McAvoy. Teddy is the middle child of three sons. His mother and father worked in overseas development organizations such as Peace Corps and USAID. This allowed him to travel to Jamaica from the age of 2 years old until 6 years of age. Here he was received basic schooling in a one room school house managed by Mrs. Hall. After living in Jamaica the family moved to Pine Island, FL. Teddy lived in Pine Island, FL and Cape Coral, FL from second grade until sixth grade. He attended elementary school at Pine Island Elementary, Franklin Park Elementary, and Lee Middle School. Both Franklin Park and Lee Middle were science and technology magnet schools. Again the family moved, this time to Swaziland in southern Africa. In Swaziland, Teddy attended a private secondary school named Waterford Kamhlaba. Interestingly the children of former President of South Africa, Nelson Mandela attended this school during the apartheid era. The family returned to Pine Island, Fl. Teddy attended high school at Mariner High School in Cape Coral, Florida, There he excelled in both academics and wrestling. After graduating high school in 2000, Teddy was accepted to the University of Florida. Teddy has been at the University of Florida, since the fall of 2000. Interestingly his time spent at the university has been the longest he has ever lived in the same city. Teddy graduated and received his bachelor of science degree in horticultural sciences in the department in the fall of 2005. Teddy started his Masters program in the spring of 2006 in the Horticultural Sciences Department with an emphasis in Weed Science under the direction of advisor Dr. William Stall. His master's project focused on fallow weed control in Florida vegetable crops. He received his M.S. from the University of Florida in the spring of 2009.