CHAPTER 3. Results and Discussion

3.1. Effects of Cropping System and Herbicide Treatment on Total Weed Biomass and Corn Yield

3.1.1. 1998 Middlesex County: Significant effects of cropping system, herbicide treatment, and of the interaction between these factors were observed for both weed biomass and corn yield in the 1998 Middlesex county experiment (Table 3.1.). Total weed biomass from control plots was approximately six times greater in the full-season system than in the double-crop system. The weed infestation in the full-season system was comprised primarily of redroot pigweed (*Amaranthus retroflexus* L.) and common lambsquarters, while the double-crop infestation was comprised of much lower levels of redroot pigweed and carpetweed (Table 3.2.).

Because annual broadleaf weeds comprised the majority of the weed infestation in both cropping systems, atrazine-containing preemergence treatments consistently provided significant reductions in weed biomass relative to the control (Table 3.3.). Neither the addition of paraquat or metolachlor to atrazine, nor the addition of paraquat plus metolachlor, resulted in additional reductions in weed biomass in either system. Similarly, the use of postemergence treatments of either dicamba plus primisulfuron and prosulfuron or glyphosate following preemergence atrazine did not reduce weed biomass relative to atrazine alone. The use of the

standard postemergence treatment alone provided only a 35 % reduction in weed biomass relative to the control in the full-season system, but provided essentially complete weed control in the double-crop system. Glyphosate, however, provided essentially complete weed control in both systems.

Corn yield was generally much lower in the double-crop system compared to the full-season system (Table 3.4). Moisture stress was the major yield limiting factor in both full-season and double-crop systems. The prolonged severe drought in late July and August reduced corn yields of the double-crop system more than the full-season system. Competition from weeds was also a major constraint to yield within both cropping systems. In both full-season and double-crop systems, treatments containing atrazine significantly improved corn yield compared to the control. The addition of paraquat to atrazine did not result in increased yield in either system, however, metolachlor treatments supplemented by paraquat in the full-season system resulted in significantly higher yields compared to metolachlor alone. The addition of postemergence glyphosate treatments following preemergence atrazine containing treatments did not produce increased yields in either system. However, postemergence glyphosate treatments following metolachlor alone or in combination with paraquat significantly increased yield in the full-season system. In the double-crop system a significant increase in yield occurred when glyphosate application followed preemergence atrazine plus metolachlor treatments as compared to the standard postemergence treatment of dicamba plus primisulfuron and prosulfuron following preemergence herbicides. Postemergence glyphosate treatments alone compared to the standard total postemergence treatment of atrazine, dicamba plus primisulfuron and prosulfuron did not significantly differ with respect to yield within either system.

Due to low precipitation amounts during the 1998 growing season (Table 2.3.), full-season corn produced significantly higher corn yields than double-crop corn within all individual herbicide treatments except the paraquat alone treatment. Yield in the atrazine treatment in the full-season system was three times greater than the double-crop system. The yield in the remainder of the treatments besides paraquat alone was approximately two to three times greater in the full-season system than the double-crop system.

In the double-crop system the mulch supplied by the previous barley crop caused a large reduction in weed biomass. Due to the nature of the weed infestation present at this location, atrazine alone also caused a large reduction in weed biomass and a substantial increase in yield in both cropping systems. Neither the addition of paraquat, metolachlor nor a postemergence treatment to atrazine caused significant additional reductions in weed biomass or increase in yield in either system. Due to weed size and composition, the standard postemergence treatments in the full-season system did not provide complete or satisfactory weed control, but did in the double-crop system. Glyphosate alone provided essentially complete reduction in weed biomass in both systems. Yield in glyphosate alone treatments was reduced in full-season corn compared to preemergence atrazine treatments due to early weed competition. In double-crop corn, stubble and straw provided by the previous barley crop suppressed weed levels sufficiently to allow glyphosate alone treatments to provide equal weed control levels and yields compared to preemergence atrazine treatments.

3.1.2. 1999 New Kent County: Significant effects of cropping system, herbicide treatment, and the interaction between these factors were observed for both weed biomass and corn yield

in the 1999 New Kent county experiment (Table 3.1.). Total weed biomass from control plots was approximately eleven times greater in the full-season system than in the double-crop system (Table 3.5.). Redroot pigweed was the primary weed species present in the full-season system with lower levels of ivyleaf morningglory (*Ipomoea hederacea* (L.) Jacq.), jimsonweed, and common cockleburr (*Xanthium stramonium* L.). The double-crop system had a relatively even distribution of ivyleaf morningglory, and light and variable infestations of fall panicum and redroot pigweed.

Because the primary weed species in the full-season system was redroot pigweed, atrazine containing preemergence treatments consistently caused significant reductions in weed biomass relative to the control (Table 3.3.). In the double-crop system, however, no significant reductions in weed biomass relative to the control treatment were observed. This result occurred because the majority of the treatments applied were fairly effective in control of the redroot pigweed present in the double-crop system, and generally not effective in control of the ivyleaf morningglory. The standard postemergence treatment of dicamba and primisulfuron plus prosulfuron following residual preemergence treatments, or sequential applications of glyphosate greatly reduced weed biomass relative to the control, but these differences were not significant statistically. In the full-season system the addition of paraquat or metolachlor to atrazine treatments did not result in additional reductions in weed biomass. Metolachlor in combination with paraquat did not provide acceptible weed control. Postemergence treatments of either dicamba and primisulfuron plus prosulfuron or glyphosate following preemergence atrazine significantly reduced weed biomass relative to atrazine alone. Weed biomass resulting from standard postemergence treatments of atrazine, dicamba and primisulfuron plus prosulfuron or

single glyphosate applications did not differ from biomass with atrazine alone. However, sequential glyphosate treatments did significantly reduce weed biomass compared to both the atrazine alone treatment or the standard postemergence treatment.

Corn yield in the control was not significantly different between the two cropping systems (Table 3.4.). In both full-season and double-crop systems, treatments containing atrazine significantly increased corn yield as compared to their respective controls. The addition of paraquat or glyphosate to any atrazine containing treatment did not increase yield in either cropping system. The addition of paraquat or glyphosate to metolachlor alone did not increase yield in the full-season system. However, postemergence glyphosate treatments following metolachlor alone did significantly increase yield in the double-crop system. Standard postemergence treatments following preemergence herbicides did not significantly increase yield statistically compared with early postemergence applications of glyphosate following preemergence treatment of atrazine plus metolachlor in either system, however a twelve bushel increase did occur in the full-season system. Single applications of glyphosate compared to the standard postemergence treatment of atrazine, dicamba and primisulfuron plus prosulfuron resulted in increased yield in the full-season system and decreased yield in the double-crop system. Yields resulting from sequential glyphosate treatments did not differ from yields resulting from the standard postemergence treatment in the double-crop system.

In the double-crop system mulch supplied by the previous barley crop caused a large reduction in weed biomass and changed the weed spectrum present. Atrazine alone caused a large reduction of weed biomass and subsequent increase in yield in the full-system, while no differences in weed biomass as a function of herbicide treatment were observed in the double-

crop system. Yield in the double-crop system was significantly increased due to atrazine. Yield resulting from early post applications of glyphosate following preemergence treatments varied at this location due to differential weed densities and species composition in the full-season system. Yield in the full-season system was significantly higher when residual preemergence herbicides were applied alone compared to the double-crop system. Standard postemergence treatments following preemergence herbicides or single glyphosate applications following atrazine significantly reduced total weed biomass and increased yield in the full-season system compared to atrazine alone. There was no difference in yield within cropping systems with a single glyphosate application compared to yield from atrazine alone.

3.1.3. 1998 Amelia County: Significant effects of herbicide treatment and of the interaction between cropping system and herbicide treatment were observed for the weed biomass variable in the 1998 Amelia county location, while the effect of cropping system was not statistically significant. Significant effects were also observed for the main and interaction effects for corn yield (Table 3.1.). The weed infestation in the full-season system consisted primarily of common lambsquarters, giant foxtail (*Setaria faberi* Herrm.), horseweed (*Conyza canadensis* (L.) Cronq.) and lower levels of a variety of other annual broadleaves. Control plots in the double-crop system had approximately one-half the amount of weed biomass observed in the full-season system, and this infestation was comprised primarily of common lambsquarters, giant foxtail and redroot pigweed (Table 3.6.).

The difference in weed biomass was not significantly different between the full-season and double-crop systems because the weed infestation at this location was relatively low and the

species present were effectively controlled by most treatments (Table 3.7.). An increase in weed biomass occurred in the double-crop paraquat plus metolachlor treatment as compared to the full-season system. All other treatments resulted in no significant weed biomass differences between the two systems.

Atrazine alone provided essentially complete weed control in both systems. The addition of metolachlor, paraquat, single or sequential glyphosate treatments or standard postemergence treatments of dicamba plus nicosulfuron to preemergence atrazine containing treatments did not reduce weed biomass compared to atrazine alone in either systems. Preemergence metolachlor alone, paraquat and paraquat plus metolachor resulted in significantly higher total weed biomass compared to atrazine alone in the full-season system. However, in the double-crop system, weed biomass resulting from metolachlor alone was not significantly different than the weed biomass resulting from atrazine alone, while paraquat alone and the combination of paraquat and metolachlor resulted in significantly higher levels of weed biomass compared to atrazine alone. Standard postemergence treatments of atrazine, dicamba and nicosulfuron without preemergence herbicides and early postemergence applications of glyphosate alone provided equivalent overall weed control compared to atrazine alone in both systems.

Corn yield was generally lower in the double-crop system compared to the full-season system (Table 3.8.). Lack of late season rainfall for double-crop corn development was the primary cause for significant differences between the two cropping systems with respect to yield. In the full-season system, atrazine containing treatments significantly improved corn yield compared to the control. Only the addition of preemergence metolachlor plus an early postemergence application of glyphosate significantly increased corn yield compared to atrazine

alone in the full-season system. No treatment increased corn yield in the double-crop system as compared to atrazine alone. The addition of a preemergence paraquat treatment or a postemergence glyphosate treatment to metolachlor alone significantly improved corn yield in the full-season system. In the full-season system, glyphosate alone or standard postemergence treatments of atrazine, dicamba and nicosulfuron resulted in significantly lower yields compared to atrazine alone, but were essentially equal in the double-crop system. The lower yields in the full-season system resulting from total postemergence treatments occurred due to early weed competition that was successfully eliminated by the preemergence atrazine treatment. In the double-crop system, however, the barley mulch suppressed early weed competition enough to allow total postemergence treatments to be effective.

Yield differences between the two cropping systems were the result of a lack of August rainfall for double-crop corn development. Due to the nature of the weed infestation, atrazine alone caused a large reduction in weed biomass and substantial yield increases in the full-season system. Only the addition of preemergence metolachlor plus early postemergence glyphosate to atrazine increased yield significantly in the full-season system compared to atrazine alone, while no treatment resulted in significantly higher yield in the double-crop system compared to atrazine alone. Metolachlor alone did not provide effective weed control in the full-season system and a significant reduction in yield compared to atrazine alone was observed. Total postemergence treatments were effective in reducing weed biomass in both systems. However, total postemergence treatments resulted in significantly lower yields compared to atrazine alone in the full-season system, whereas total postemergence treatments in the double-crop system did not result in significant yield reductions compared to the atrazine alone.

3.1.4. 1999 Amelia County: The only significant effects in the 1999 Amelia county experiment were herbicide treatment on weed biomass and cropping system on corn yield. The remainder of the factors and the interaction between the two main factors were not statistically significant (Table 3.1.). This location had a minimal weed infestation present in either cropping system and consisted primarily of giant foxtail (*Setaria faberi* Herrm.). The double-crop system, however, had a substantial increase in the percentage of total weed biomass represented by pitted morningglory (*Ipomoea lacunosa* L.) (Table 3.9.). Total weed weights were only one and one half times greater in the full-season system compared to the double-crop system.

Atrazine containing treatments consistently provided significant reductions in weed biomass relative to the control in both systems (Table 3.7.). No further reductions in weed biomass were observed due to the addition of paraquat, metolachlor, postemergence glyphosate applications or the standard postemergence treatment of dicamba and nicosulfuron to the atrazine treatment in either cropping system. Metolachlor alone and paraquat alone resulted in significantly higher levels of weed biomass compared to atrazine alone in the full-season system. The only treatments in the double-crop system which resulted in significantly higher weed biomass compared to the atrazine alone were the paraquat plus metolachlor treatment and the control. Standard total postemergence treatments of atrazine, dicamba and nicosulfuron or single and sequential applications of glyphosate provided essentially complete weed control in both systems that was not significantly different from control with atrazine alone.

The only significant effect on corn yield was due to cropping system. Herbicide treatments acted similarly between the two systems and, due to the exceptionally low levels of weed infestation, yield from control plots was equivalent to yield from plots treated with atrazine in both cropping systems (Table 3.8.). Significant increases in yield were observed when metolachlor was added to atrazine alone in the full-season system, but not in the double-crop system. The addition of paraquat, standard postemergence treatments of dicamba and nicosulfuron or early post applications of glyphosate did not significantly increase yields as compared to the preemergence combination of atrazine plus metolachlor in the full-season system or atrazine alone in the double-crop system. Yield from plots treated with single or sequential glyphosate applications were equivalent to yields from the atrazine plus metolachlor treatment in full-season and atrazine alone in the double-crop system. Differential yields occurred between cropping systems because full-season corn received adequate rainfall, while double crop corn experienced drought conditions during critical developmental periods of silking, tassle and grain fill.

Due to the extremely low level of weeds present at this location significant effects on weed biomass were observed for herbicide treatment only. Preemergence atrazine plus metolachlor provided adequate weed control to allow significant increases in yield in the full-season system, while paraquat plus atrazine resulted in significantly increased yields in the double-crop system compared to atrazine alone. The addition of metolachlor to atrazine did not increase yields in the double-crop system compared to atrazine alone, however the addition of paraquat did result in increased yields. Total postemergence treatments were as effective in reducing weed biomass and maintaining yield as the preemergence treatment of atrazine plus metolachlor in full-

season and the atrazine alone in double-crop primarily due to the abnormally low weed infestaion at this location.

3.1.5. 1998 Montgomery County: Significant effects of cropping system, herbicide treatment and of the interaction between these factors were observed for weed biomass in the 1998 Montgomery county location. Significant effects of corn yield did not occur in response to the cropping system variable, but did for herbicide treatment and for the interaction effect (Table 3.1.). Total weed biomass from control plots was approximately five times greater in the full-season system than the double-crop system. The primary weed species in the full-season system was barnyardgrass which comprised two-thirds of the total weed biomass, and jimsonweed accounting for approximately thirty percent (Table 3.10.). The majority of total weed biomass in the double-crop system was barnyardgrass.

Because the majority of the weed infestation was barnyardgrass, treatments containing metolachlor in the full-season system consistently reduced weed biomass compared to both the control and atrazine alone treatments (Table 3.11.). In the double-crop system, neither metolachlor nor atrazine alone significantly reduced weed biomass relative to biomass in the control treatment. The combination of atrazine and metolachlor did not significantly reduce weed biomass relative to atrazine alone in the full-season system, but did in the double-crop system. The addition of paraquat to preemergence treatments of atrazine, metolachlor or the combination of the two resulted in significant reductions in weed biomass in the full-season system. The addition of paraquat to atrazine or metolachlor alone resulted in a significant

reduction in weed biomass in the double-crop system, but did not effect weed biomass compared to the combination of metolachlor and atrazine.

Preemergence treatments supplemented by early postemergence applications of glyphosate or standard postemergence treatments of dicamba plus nicosulfuron significantly reduced weed biomass compared to metolachlor plus atrazine in the full-season system, however significant reductions did not occur in the double-crop system. Standard total postemergence treatments of atrazine and dicamba plus nicosulfuron did not provide weed control equivalent to single or sequential applications of glyphosate in the full-season system, but produced essentially complete weed control in the double-crop system. A significant reduction in weed biomass was due to paraquat alone compared to the atrazine plus metolachlor treatment. This result indicates that the majority of the barnyardgrass was emerged when the full-season treatments were applied and minimal germination occurred subsequent to treatment. The addition of paraquat to preemergence treatments was a necessary component at this location for acceptable weed control in the full-season system. However in the double crop system, the addition of paraquat did not significantly affect weed control.

Significant effects of corn yield due to cropping system did not occur because double-crop corn received adequate rainfall to facilitate crop growth and development. Metolachlor alone produced a significant increase in yield in the full-season system relative to atrazine alone, but this effect was not observed in the double-crop system (Table 3.12.). The addition of atrazine to metolachlor increased yields in both systems. The use of paraquat in combination with any preemergence treatment significantly increased yield in the full-season system, but no similar effect was observed in the double-crop system. Early post applications of glyphosate

subsequent to any preemergence treatment did not significantly increase yield in the full-season system compared to any preemergence treatment containing paraquat. Significant increases did occur when postemergence glyphosate treatments or standard postemergence treatments of dicamba plus nicosulfuron were added to any preemergence treatment containing atrazine. Yields attained from standard total postemergence treatments of atrazine plus dicamba and nicosulfuron were significantly lower compared to yields from glyphosate alone in either system. Yields from single total postemergence treatments of glyphosate did not significantly differ from yields resulting from treatments of paraquat plus metolachlor in the full-season system or atrazine alone in the double-crop system. The use of preemergence treatments of paraquat plus early postemergence applications of glyphosate produced significant increases in yield in the full-season system compared to glyphosate alone, but did not affect double-crop yields. This result occurred because paraquat eliminated early competition in the full-season system, while the mulch supplied by the barley crop provided weed suppression sufficient to minimize early weed competition and allowed total postemergence applications of glyphosate to be efficacious.

Significant effects on corn yield did not occur due to cropping system because double-crop corn received adequate late season rainfall. The addition of paraquat to preemergence treatments was necessary to provide acceptable weed control and allow significant increases in yield in the full-season system. However, the addition of paraquat was not advantageous in the double-crop system because stubble and straw from the barley crop provided an effective mulch to suppress the barnyardgrass infestation. The use of atrazine alone did not provide adequate weed control in either system. The addition of early post-applications of glyphosate did not increase yield in the full-season system compared to any preemergence treatment

containing paraquat. Total postemergence glyphosate treatments were significantly better in weed control than the standard postemergence treatment of atrazine, dicamba plus nicosulfuron and also resulted in significantly higher yields. Yields resulting from applications of glyphosate following preemergence paraquat were greater than yields from glyphosate alone in the full-season system. The beneficial effect of preemergence paraquat application was not observed in the double-crop system.

3.1.6. 1999 Montgomery County: The effects of herbicide treatment and of the interaction between the cropping system and herbicide treatment were observed to be significant in respect to weed biomass, whereas no significant effects of the cropping system variable were observed in the 1999 Montgomery county experiment. Significant effects were observed for both main factors and their interaction for corn yield (Table 3.1.). Total weed biomass in the full-season control was greater than three and one half times larger than in the double-crop control. The weed infestation in the full-season experiment consisted primarily of large crabgrass (*Digitaria sanguinalis* (L.) Scop.) and lower levels of various annual and perennial broadleaf species. The double-crop infestation consisted almost entirely of large crabgrass (Table 3.13.). The decision to use the selective post-emergence treatment of dicamba plus halosulfuron was inappropriately chosen at this location. Early in the year yellow nutsedge and perennial broadleafs appeared to be the major weed species at this location, however subsequent to early postemergence applications in the full-season experiment, substantial germination of large crabgrass occurred. As a result of this late large crabgrass germination, the early

postemergence applications of dicamba plus halosulfuron following preemergence treatments or the total postemergence treatment of atrazine and dicamba plus halosulfuron were ineffective.

No significant effects of cropping system were observed with respect to weed biomass at this location. Atrazine alone was effective in significantly reducing weed biomass as compared to the control, however, the heavy infestation of large crabgrass was not controlled by this treatment (Table 3.11.). For this reason, metolachlor alone provided significant reductions in weed biomass compared to atrazine alone, and the combination of the two resulted in significantly lower levels of weed biomass as compared to individual preemergence treatments in the full-season system. In the double-crop system metolachlor alone resulted in significant reductions in weed biomass compared to either the control or atrazine alone, and the combination of the two resulted in no further biomass reductions. The addition of paraquat to any preemergence treatment resulted in significant weed biomass reductions in the full-season system. Increases in weed control were observed when paraquat was added to atrazine alone in the double-crop system, but no effect occurred when paraquat was added to metolachlor alone or in combination with atrazine. Early postemergence treatments of glyphosate were not significantly different in respect to weed biomass than preemergence treatments combined with paraquat in the full-season system. The addition of early postemergence glyphosate to paraquat plus atrazine did result in significant reductions of weed biomass compared to the paraquat plus atrazine combinations. Sequential postemergence glyphosate treatments resulted in significant reductions of weed biomass compared to single glyphosate treatments or single early postemergence treatments following preemergence paraquat alone in full-season, but similar reductions in weed biomass in the double-crop system were not observed.

Yields were significantly increased in the full-season system with atrazine alone as compared to the control, metolalachlor alone, paraquat alone or the standard total postemergence treatment of atrazine plus dicamba and halosulfuron (Table 3.12.). Atrazine alone in the double-crop system only resulted in significant increases in yield when compared to the control and paraquat alone. The addition of paraquat to preemergence treatments of atrazine or metolachlor alone significantly increased yields in the full-season system compared to atrazine or metolachlor alone, but did not result in an increase in yield in the double-crop system. However, the addition of paraquat to the combination of atrazine and metolachlor increased yield in both systems compared to atrazine plus metolachlor. Early postemergence treatments of glyphosate following any preemergence treatment containing paraquat resulted in significant increases in yield in both systems, except for paraquat plus the combination of atrazine and metolachlor in the double-crop system. Single total postemergence treatments of glyphosate resulted in significantly lower yields than any preemergence treatment combined with paraquat in the full-season system. Significantly different yields were not observed for single postemergence treatments of glyphosate in the double-crop system compared to any preemergence treatment containing paraquat in the double-crop system. In both systems, total postemergence glyphosate treatments resulted in increased yields compared to the standard total postemergence treatment of atrazine plus dicamba and halosulfuron.

Preemergence metolachlor alone treatments were observed to result in significantly lower weed dry weights than atrazine alone, however, atrazine alone resulted in significantly higher yields. This result occurred because metolachlor was efficacious in the control of large crabgrass, but did not affect the weeds present at planting. Therefore, these weeds competed

with corn the entire growing season, whereas atrazine alone reduced early weed competition and allowed improved early corn development. Increased weed biomass in the atrazine plots occurred due to the late flush of large crabgrass which was not effectively controlled by atrazine alone. Standard total postemergence treatments of atrazine plus dicamba and halosulfuron were chosen inappropriately in this experiment due to lack of prior knowledge of the heavy large crabgrass infestation. Therefore, treatments containing dicamba and halosulfuron were not effective and treatments containing other selective products would have been more efficacious. The addition of paraquat to preemergence treatments was essential to reduce early weed competition and increase yield in the full-season system. Supplemental early postemergence glyphosate following the latter treatment further increased yields by eliminating the late flush of large crabgrass. Early postemergence treatments of glyphosate also increased yields and decreased weed biomass in the double-crop system by eliminating the late flush of large crabgrass, however the addition of paraquat did not cause any increase in yield because early weed competition was reduced by barley mulch.

3.2. Effect of cropping system and herbicide treatment on control of specific weed species

3.2.1. Ivyleaf Morningglory in New Kent county, 1999: The 1999 New Kent county location contained a relatively uniform infestation of ivyleaf morningglory in both cropping systems. This situation allowed investigation of the efficacy of early postemergence applications of glyphosate as compared to standard postemergence treatments of dicamba plus primisulfuron and prosulfuron following residual preemergence treatments. Total postemergence treatments of single and sequential glyphosate treatments and standard total postemergence treatments of atrazine plus dicamba plus primisulfuron and prosulfuron were also investigated in both cropping systems.

Statistical analysis revealed that there were significant effects of cropping system, herbicide treatment and of the interaction between these two factors in terms of ivyleaf morningglory control. Results indicate that the addition of paraquat to preemergence treatments of atrazine plus metolachlor or early postemergence treatments of glyphosate does not increase ivyleaf morningglory control compared to the combination of atrazine plus metolachlor in either system (Table 3.14.). Standard postemergence treatments of dicamba plus primisulfuron and prosulfuron following residual preemergence herbicides resulted in significantly greater control of ivyleaf morningglory as compared to early postemergence glyphosate treatments following residual preemergence herbicides in both systems. Total postemergence treatments of atrazine plus dicamba plus primisulfuron and prosulfuron also resulted in significantly greater ivyleaf

morningglory control compared to single total postemergence treatments of glyphosate. In the full-season system, sequential applications of glyphosate resulted in significantly greater ivyleaf morningglory control compared to the standard total postemergence treatment, however, in the double-crop system, the standard postemergence treatment resulted in significantly greater ivyleaf morningglory control compared to sequential glyphosate treatments. Single total postemergence treatments of glyphosate did not provide acceptible ivyleaf morningglory control in the full-season system, but provided more effective control in the double-crop system.

Ivyleaf morningglory is relatively difficult to control, and can result in reduced yields and impair the ability to harvest effieciently (SWSS, 1994). The stubble and straw from the barley crop generally increases the ability to control ivyleaf morningglory in the double-crop system compared to the full-season system. Standard total postemergence treatments following residual preemergence treatments of atrazine plus metolachlor resulted in significantly greater ivyleaf morningglory control compared to glyphosate following atrazine plus metolachlor treatments in both systems. The addition of paraquat to any treatment in either system did not significantly increase ivyleaf morningglory control. The standard total postemergence treatment of atrazine plus dicamba plus primisulfuron and prosulfuron resulted in significantly greater weed control compared to single total postemergence treatments of glyphosate. Results indicate that acceptible control of ivyleaf morningglory will more likely result from use of standard selective postemergence treatments than use of glyphosate.

3.2.2. Perennial Trumpetcreeper and annual broadleaf control with or without early postemergence glyphosate treatments in Middlesex county, 1998: In Middlesex county

in 1998 a light, but uniform infestation of the perennial broadleaf trumpetcreeper was present, and the location also contained modest infestation levels of the annual broadleaf species common lambsquarters, redroot pigweed and ivyleaf morningglory. This situation allowed investigation of trumpetcreeper control afforded by early postemergence treatments of glyphosate with or without preemergence treatments.

Statistical analysis revealed that control of trumpetcreeper was not significantly different between cropping systems, and therefore results of trumpetcreeper control from the double-crop system are presented. (Table 3.15.). Results indicate that paraquat was not effective in control on any species. Treatments that contained atrazine without postemergence applications of glyphosate provided acceptible control of annual broadleafs, but no control of the perennial trumpetcreeper. The addition of early postemergence glyphosate to any treatment containing atrazine resulted in essentially complete annual broadleaf control, coupled with acceptible levels of trumpetcreeper control. Total postemergence glyphosate treatment resulted in effective control of annual broadleafs and acceptible levels of trumpetcreeper control, however, a reduction in corn vigor due to early weed competition was observed. The addition of preemergence paraquat or atrazine to early postemergence glyphosate significantly increased corn vigor and provided essentially complete annual broadleaf control and acceptible control levels of trumpetcreeper.

The weed control ratings for this experiment were taken on the eighteenth of August and trumpetcreeper control levels at this time were greater than observed at the end of the growing season (Data not presented). Early postemergence treatments of glyphosate were effective in

eliminating trumpetcreeper competition in this year, however, trumpetcreeper levels may not be significantly reduced by these treatments in the following season.

3.2.3. Barnyardgrass control in full-season and double-crop corn with early postemergence glyphosate treatments in Montgomery county, 1998: The 1998 experiment in Montgomery county contained an extremely dense infestation of barnyardgrass (Table 3.10.). Control of barnyardgrass was evaluated with residual preemergence herbicides alone, in combination with paraquat and with or without early postemergence treatments of glyphosate in both cropping systems. Early postemergence treatments of glyphosate alone or in combination with preemergence paraquat were also evaluated (Table 3.16.). Statistical analysis demonstrated no significant effect of the cropping system variable, but a highly significant effect of the herbicide treatment variable for barnyardgrass control.

Results indicated that residual preemergence treatments containing metolachlor were generally more effective in the double-crop system than the full-season system for barnyardgrass control. Paraquat alone was more effective for barnyardgrass control in the full-season system than the double-crop system. This result occurred because a greater amount of barnyardgrass was emerged at the time of paraquat application in the full-season system, and the mulch created from the barley crop caused the majority of barnyardgrass to emerge subsequent to paraquat treatment in the double-crop system. The addition of paraquat to any residual preemergence herbicides significantly increased barnyardgrass control in the full-season system, but only significantly increased barnyardgrass control in the double-crop system when applied in combination with metolachlor containing treatments. Single total postemergence treatments of

glyphosate resulted in significant increases in barnyardgrass control compared to any residual preemergence treatment with or without addition of paraquat in both systems. Barnyardgrass control was not improved if residual preemergence herbicides with or without paraquat or paraquat alone were applied prior to early postemergence glyphosate treatment compared to early postemergence glyphosate treatment alone in both cropping systems.

Glyphosate treatment alone provided superior barnyardgrass control in both cropping systems as compared to any treatment lacking a glyphosate component and equal control to any treatment containing a glyphosate component. Preemergence residual treatments generally provided increased barnyardgrass control in the double-crop system as compared to the full-season system, however, barnyardgrass control was not increased to acceptible levels in either system with these treatments.

As discussed previously with respect to overall weed biomass and corn yield, the addition of paraquat to preemergence treatments was necessary to provide acceptible weed control and allow significant increases in yield in the full-season system. However, the addition of paraquat was not advantageous in the double-crop system because stubble and straw from the barley crop provided an effective mulch to suppress the barnyardgrass infestation. The addition of early postemergence applications of glyphosate did not increase yield in the full-season system compared to any preemergence treatment containing paraquat. Yields resulting from applications of glyphosate following preemergence paraquat were greater than yields from glyphosate alone in the full-season system. Yields from single total postemergence treatments of glyphosate did not significantly differ from yields resulting from treatments of paraquat plus metolachlor in the full-season system or atrazine alone in the double-crop system.

3.2.4. Comparison of the utility of paraquat in full-season and double-crop systems in Montgomery county, 1998: Residual preemergence treatments with or without paraquat were compared with respect to yield in the 1998 Montgomery county location for both the full-season and double-crop system (Table 3.17.). This location contained a dense infestation of barnyardgrass (Table 3.9.). Results indicated that the addition of paraquat in the full-season system significantly increased yield when applied in addition to any residual preemergence herbicide treatment and the control. However, the addition of paraquat to any preemergence treatment or the control in the double-crop system resulted in no significant increase in yield.

Significant increases in yield in the full-season system occurred because preemergence paraquat effectively controlled the emerged barnyardgrass at the time of application, while the residual preemergence herbicides alone had limited activity on emerged barnyardgrass. Minimal barnyardgrass germination occurred subsequent to premergence herbicide treatment in the full-season system which resulted in equivalent yields from paraquat alone. Therefore at this location, the addition of paraquat was a necessary component for effective weed control and increased yields. In the double-crop system, the stubble and straw supplied by the harvest of the barley crop provided an effective mulch, which suppressed and delayed the emergence of barnyardgrass. Thus, low amounts of barnyardgrass were emerged at the time of preemergence herbicide application and the addition of paraquat to residual preemergence herbicides was of no benefit in terms of yield.

3.3. Corn yield differences due to rainfall amounts

3.3.1. Corn yield differences due to differential rainfall between the 1998 and 1999 growing season for full-season and double-crop corn in Amelia county:

Corn yield differences were compared between the 1998 and 1999 in the full-season (Table 3.18.) and double-crop (Table 3.19.) systems to determine the effect of differential rainfall amounts in Amelia county. For this comparison the five best treatments were choosen in terms of yield for both the full-season and double-crop system. In the 1998, both the full-season system and double-crop system experienced extended periods of drought throughout the entire growing season. However, in the 1999 growing season, adequate rainfall was received for both cropping systems to facillitate corn development. At this location, results indicated that differential rainfall resulted in no significant increase in corn yield in the full-season system within individual herbicide treatments between growing seasons. However, in the double-crop system, significant yield increases occurred for all herbicide treatments between growing seasons.

Increased corn yields in the double-crop system in 1999 indicated double-crop corn appeared to be more susceptible to drought than full-season corn. Higher drought susceptibility in the double-crop system is a result of a shorter developmental period than the full-season system, and therefore lack of rainfall in 1998 resulted in significant reductions of corn yield compared to the 1999 growing season.

3.4. Economic characteristics of full-season and double-crop corn production systems

The net returns from the full-season and double-crop corn production systems were calculated based on corn and barley crop production budgets for Virginia (Virginia Cooperative Extention, 2000). The cost of seed, fertilizer, lime, pesticides other than herbicides, application, fuel, harvest, and labor are contained in tables 3.20. and 3.21. Cost of inputs for herbicide treatments in both systems were calculated using values as presented in table 3.22. Overall returns in individual treatments were calculated using mean yield values for the treatments and a corn grain value of $0.11/kg. In the double-crop system, barley yields were field averages for the specific year and location with a barley value of $0.09/kg. Both corn and barley prices were calculated as averages of the past five years. In these experiments, the hybrid utilized was choosen for tolerance to postemergence applications of glyphosate and insect protection provided by the incorporation of the Bt gene. Alternative hybrids may have been better suited to this production system, however, the focus of this experiment was elucidation of herbicide inputs required in the two cropping systems. Better yields and net returns would likely have resulted from selection of a more appropriate hybrid. Cropping system evaluation of double-crop vs full-season corn in similar research indicate the potential to increase double-crop corn yields due to the selection of better suited hybrids (Alley, 1999).

3.4.1. Middlesex county 1998: In the 1998 Middlesex county experiment the majority of the weed infestation consisted of annual broadleaf species (Table 3.2.) Therefore, atrazine alone was sufficient to prevent yield loss due to competition from weeds. No increase in herbicide input value relative to the cost of atrazine alone resulted in a significant increase in corn yield. Similary, atrazine alone provided excellent weed control in the double-crop system, and

no greater herbicide input resulted in significantly greater corn yield than that from plots treated with atrazine alone. In this experiment drought was experienced throughout most of the growing season, and plots treated with atrazine alone produced corn yields of only 4327 and 1443 kg/ha in the full-season and double-crop systems respectively. In the double-crop system, the barley crop yielded 5376 kg/ha. Corn yield in the full-season system resulted in a negative net return of $19.77/ha when production costs were subtracted. In the double-crop system, a negative net return of $153.20/ha was observed after barley and corn production costs were subtracted.

3.4.2. New Kent county 1999: In the 1999 New Kent county experiment, annual broadleaf species comprised the majority of the weed infestation and included a heavy infestation of ivyleaf morninglglory. (Table 3.5.). Preemergence atrazine plus a single postemergence application of glyphosate provided adequate weed control and allowed corn yields that were not significantly different from corn yields resulting from treatments containing additional herbicidal inputs in the full-season system. In the double-crop system, both atrazine plus metolachlor were required for adequate weed control and to prevent yield loss due to competition. No increase in herbicide input relative to the cost of atrazine plus metolachlor resulted in a significant increase in yield in the double-crop system.

The presence of a dense infestation of ivyleaf morningglory at this location could have resulted in additional yield losses, fuel, and repair costs due to the vining growth habit of the species. Additional herbicidal inputs could have been advantageous to improve the ability to harvest effectively.

In this experiment sufficient rainfall occurred to allow corn development throughout the entire growing season in both cropping systems. Plots in the full-season system treated with preemergence atrazine plus single postemergence glyphosate resulted in corn yields of 5017 kg/ha and positive net returns of $34.59/ha. In the double-crop system, corn plots treated with atrazine plus metolachlor yielded 4516 kg/ha, and the barley crop yielded 3870 kg/ha. A positive net return of $12.35/ha was observed in the double-crop system.

3.4.3. Amelia county 1998: In the 1998 Amelia county experiment, atrazine alone was sufficient to prevent yield loss due to competition from weeds in both cropping systems. No increase in herbicide input value relative to the cost of atrazine alone resulted in a significant increase in corn yield in either system. Atrazine alone was efficacious in weed control because the weed infestation at this location consisted primarily of annual broadleaf species, and triazine resistant weed species were also not present (Table 3.6.). In this experiment rainfall was the primary constraint on corn yield and sufficient precipitation allowed crop development in the full-season system, which resulted in corn yields of 5707 kg/ha in plots treated with atrazine alone. However, drought was experienced during the critical corn developmental stages in the double-crop system, and corn yields of only 1631 kg/ha were observed in plots treated with atrazine alone. A positive net return of $129.72/ha was observed in the full-season system. The poor corn yields in the double-crop system resulted in a negative net return of $182.85/ha, despite the harvest of 4838 kg/ha of barley prior to double-crop corn planting.

3.4.4. Amelia county 1999: In the 1999 Amelia county experiment extremely low populations of annual broadleaf and grass species were observed (Table 3.9.). The majority of herbicide treatments applied in both cropping systems provided adequate weed control. A single early postemergence application of glyphosate provided excellent weed control in the full-season system. No increase in herbicide input value relative to the cost of glyphosate alone resulted in a significant increase in corn yield. In the double-crop, atrazine alone and a single postemergence application of glyphosate were not significantly different from atrazine plus paraquat in terms of weed control. However, atrazine plus paraquat resulted in significantly higher yields compared to either atrazine alone or single early postemergence application of glyphosate.

In this experiment, sufficient precipitation was received throughout the growing season and allowed good corn development in both cropping systems. Plots in the full-season system treated with a single postemergence application of glyphosate produced corn yields of 6773 kg/ha, which translated into positive net returns of $232.27/ha. In the double-crop system, plots treated with atrazine plus paraquat produced corn yields of 3575 kg/ha, while the barley crop produced 4838 kg/ha. A positive net return of only $14.83/ha was observed in the double-crop system after production costs of the two crops were subtracted.

3.4.5. Montgomery county 1998: In the 1998 Montgomery county location atrazine alone did not prevent corn yield loss due to competition from weeds in either system. However, atrazine supplemented by a single early postemergence glyphosate treatment significantly increased yields as compared to atrazine alone in both cropping systems. No increase in

herbicide input value relative to the cost of preemergence atrazine plus early postemergence glyphosate resulted in a significant increase in corn yield in either cropping system. The postemergence application of glyphosate was required to effectively control the heavy barnyardgrass infestation observed in both cropping systems.

In this experiment dry conditions occurred during early full-season corn development. Adequate rainfall was received for late full-season corn development and throughout double-crop corn development. Corn from plots treated with preemergence atrazine plus early postemergence glyphosate produced yields of 5394 and 4955 kg/ha in the full-season and double-crop systems respectively. Positive net returns were observed for both cropping systems. Full-season corn yield resulted in a positive net return of $72.90/ha, whereas the double-crop system resulted in a positive net return of $219.91/ha with the combination of barley yield of 5537 kg/ha plus corn yield of 4955 kg/ha.

3.4.6. Montgomery county 1999: In the 1999 montgomery county location, preemergence atrazine supplemented by an early postemergence application of glyphosate prevented yield loss due to competition from weeds in the full-season system. No increase in herbicidal input value relative to the cost of preemergence atrazine plus early postemergence glyphosate resulted in a significant increase in corn yield. In the double-crop system, stubble and straw from the barley crop suppressed weed populations and single early postemergence treatments of glyphosate provided adequate season-long weed control. No greater herbicide input level resulted in significantly greater corn yield than that from plots treated with early postemergence glyphosate alone.

This location experienced low levels of precipitation throughout most of the growing season. Full-season corn plots treated with atrazine supplemented by a single early postemergence application of glyphosate produced 5080 kg/ha, which resulted in a postive net return of $38.91/ha. Double-crop corn plots treated with single early postemergence glyphosate produced only 2258 kg/ha, and the barley crop yielded 6182 kg/ha. A negative net return of $4.94/ha was observed due to poor corn yields resulting from dry weather conditions in the double-crop system.

In our experiments, yield from all treatments in which competition from weeds did not impede corn development averaged 2973 kg/ha in the double-crop system. In the full-season system, yield from treatments in which competition from weeds did not impede corn develpment averaged 5463 kg/ha. Taken over all experiments, the double-crop system produced 54 % of the yield of the full-season system. Assuming a similar relationship between yields in the two systems, and using historical Virginia corn and barley yields of 6184 kg/ha and 4032 kg/ha respectively, an overall economic assessment can be determined. In this scenario, full-season corn would exhibit a positive return of $190.17/ha without the subtraction of herbicidal input costs required to eliminate weed competition. In the double-crop system, corn yields of 6184 kg/ha and barley yields of 4032 kg/ha would result in a positive return of $247.94/ha without the subtraction of herbicidal input costs required to eliminate weed competition in the corn crop. However, if double-crop corn produced only 54 % of the historical Virginia average corn yield a negative return of $119.18/ha would occur without the subtraction of herbicidal input costs required to eliminate weed competition in the corn crop. Net returns in the cropping systems

could be determined by evaluation of the weed infestation at a specific location and the cost of the herbicide program needed for weed control.

3.5. Summary

Throughout the duration of these experiments, Virginia and most of the southeastern United States experienced dry weather conditions that resulted in overall reductions in corn yield. In our experiments, double-crop corn was observed to be more susceptible to dry conditions than full-season corn, due to the shorter growing season available for double-crop corn development. However, when adequate late season rainfall was received, economic return from the small grain and corn crops in the double-crop system was significantly higher than the return in the full-season system. The ability to reduce non-selective herbicidal inputs in the double-crop system were consistently observed due to the residue created by the barley crop. Stubble and straw routinely reduced weed populations and delayed weed emergence in the double-crop system. Single total postemergence applications of glyphosate were generally observed to provide adequate late-season weed control in the full-season system, however, early weed competition resulted in reduced corn yield compared to treatments containing residual preemergence herbicides. In the double-crop system, early postemergence glyphosate treatments provided excellent weed control and minimal yield reduction due to early weed competition where susceptible species were present. Perennial weed control was significantly improved with postemergence treatments of glyphosate compared to residual preemergence treatments, and equivalent control to treatments in which both preemergence and standard

postemergence herbicides were applied. Generally glyphosate resistant corn has shown the potential to be advantageous in both cropping systems depending on the specific weed infestation. Although reductions in herbicide inputs were realized in most experiments in the double-crop system, adoption depends on identification of hybrids better acclimated to the growing conditions in the double-crop system.