Axant™ Flex Cotton Weed Management Systems and Preemergence Palmer Amaranth Control Using Isoxaflutole

by

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A Thesis

In

Plant and Soil Science

Submitted to the Graduate Faculty
of Texas Tech University in
Partial Fulfillment of
the Requirements for
the Degree of

MASTER OF SCIENCE

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ACKNOWLEDGMENTS

I would like to thank Dr. Peter Dotray for his advice and guidance throughout this degree. I have gained so many valuable experiences and knowledge from Dr. Dotray that have shaped me into the weed scientist that I am today. Thank you for giving me this opportunity.

I would like to thank my committee members: Dr. Katie Lewis, Dr. Glen Ritchie, and Dr. Adam Hixson. Thank you all for answering my questions and giving me guidance throughout this process.

I would like to thank all of my co-workers and fellow graduate students: Dr. Kyle Russell, Blaine Patton, Megan Mills and Bobby Rodriguez. Thank you for all of the hours of spraying a field work to help make this project successful. Thank you all for being there to lend a helping hand when I needed it.

Finally, I would like to thank my family for their unconditional support through this process. Thank you all for having my back. I definitely could not have done it without you.

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CHAPTER I

LITERATURE REVIEW

One way to define a weed is “a plant growing where it is not wanted” (Anderson 1996). Weeds have been present in crops as long as agriculture has existed (Bell 2015). Weeds can have negative effects on crops. Of the major crop pests that include weeds, animal pests, and pathogens, weeds cause the highest potential crop loss at 34% (Oerke 2006). Handweeding is an example of one of the earliest forms of weed control. As agriculture developed, tools were made to assist in crop production but not necessarily weed control. Early weed control was not intentional, but mainly occurring through stirring of the soil for seedbed preparation (Timmons 2005). As time passed and technology improved, advances in weed control occurred from physical removal to chemical control (Timmons 2005). Weed management has changed over the years and each change presents new challenges.

Physical control of weeds encompasses many practices. Hand-pulling, hoeing, mowing, water management, smothering with nonliving material, artificially high temperatures, burning, and machine tillage are all considered methods of physical weed control (Anderson 1996). Many implements were developed throughout history to stir the soil and prepare seedbeds for planting. Most were not designed for weed control because weeds were controlled incidentally (Timmons 2005). Tillage can be used as a form of weed control. There are two types of tillage: primary and secondary (Anderson 1996). Primary tillage is conducted with the purpose of seedbed preparation and not necessarily for weed control while secondary tillage, such as cultivation, is used for the purpose of weed removal (Anderson 1996).

Chemical control of weeds came much later than chemical control of diseases and insects. Some of the earliest forms of weed control involved the use of lime and salt. Salt was used extensively on railways and highway rights-of-way in Kansas to control field bindweed (*Convolvulus arvensis* L.) between 1937 and 1950 (Yost 1939). Chemical weed control has been practiced since around 1900, but major developments didn't come until 1944 with the discovery of 2,4-D and MCPA (Anderson 1996). The discovery of these growth regulating herbicides marked the true beginning of the "Chemical Era of Agriculture" (Timmons 2005). Fluometuron was registered in 1960 and was first available for public use in 1965 (EPA 1985; Timmons 2006). The use of fluometuron was widespread and was applied on 25% of cotton (*Gossypium hirsutum* L.) planted in the United States between 1992 and 1996 (Young 2006).

Trifluralin was registered in 1963 (EPA 1996b). Trifluralin became an important herbicide in cotton production and was applied to 50% of cotton acres between 1992 and 1996 (Young 2006). Monosodium methanersonate (MSMA) was available for public use in 1963 (Timmons 2006) and was widely used prior to the introduction of glyphosate-resistant cotton (Young 2006). Prometryn received EPA registration in 1964 (EPA 1996a) and diuron a few years later in 1966 (EPA 1983). Paraquat was first available for use in 1966 and continues to be an important herbicide to cotton production (Timmons 2006; Young 2006).

Glyphosate was introduced in the 1970s. Glyphosate's high efficacy, low mammalian toxicity, and inactivity in the soil led to an increase in no-till production because of the control of perennial weeds (Appleby 2005). Acetyl Coenzyme A carboxylase inhibitors also were introduced in the 1970s. This new mechanism of action was active on most grasses and was selective in broadleaf crops (Appleby 2005). Chlorsulfuron was introduced in 1980. The introduction of this herbicide and other sulfonylureas was a major advancement because these herbicides were effective at low use rates and have low mammalian toxicity (Appleby 2005). These attributes are now the standard for herbicide registration.

Biological weed control has advanced along with physical and chemical methods. Biological control is the use of natural enemies to control a specific weed (Anderson 1996). Phytophagous insects and pathogenic fungi are the main biotic agents for biological control of terrestrial weeds, while herbivorous fish are the primary biotic agent for controlling aqueous weeds. One example of this was the use of *Cactoblastis cactorum* to control two *Opuntia* species in Australia, common prickly pear and spiny prickly pear (Anderson 1996). Gall-forming mites (*Aceria malherbae* Nuzzaci) have been used as a biological control agent on field bindweed (*Convolvulus arvensis* L.). These mites feed on field bindweed, which results in malformed growth of leaf, stem, and bud tissue. Plants severely infested with mites fail to flower and are severely stunted underground (Boydston and Williams 2004). Boydston and Williams (2004) used these gall-forming mites in combination with herbicides to help control field bindweed. Field bindweed plants infested with *A. malherbae* were 28% shorter than plants that were not infested and shoot and root biomass were reduced by 48 and 46%, respectively.

New technologies have provided new strategies for weed management over the past few years. See & Spray™ technology from John Deere® is a system that detects weeds present in the field and only applies the herbicide solution to the weed as opposed to a broadcast manner where weeds, soil, and crop, if present, are treated uniformly. See and Spray™ technology was developed by Blue River Technology, which was acquired by John Deere® in 2017 (Steadman 2021). Unmanned aerial vehicles (UAVs) are being studied in the United States for potential herbicide applications (Ozkan 2023). These technologies have been used in Asia for herbicide applications. South Korea uses these systems for 30% of agricultural spraying and Japan sprays 40% of their rice crops in this manner (Ozkan 2023). These technologies continue to be studied and could be another tool to complement traditional herbicide application methods. Electrocution of weeds has been a method of weed control that has been used in the past and it is beginning to become popular again to help control troublesome weeds. This method of weed control is possible if a height differential exists between the crop and weed. This method can be used in an integrated weed management system to control late-season escapes as well as decrease seed viability of a treated plant (Schreier et al. 2022).

Palmer amaranth (*Amaranthus palmeri* S. Wats.) is an erect summer annual and is found throughout the Southwestern United States (Rosenbaum and Bradley 2010). Palmer amaranth has often been considered a common weed in cotton production and has become one of the most troublesome in recent years. In a survey by Van Wychen (2022), Palmer amaranth was listed as the second most common and the most troublesome weed among all broadleaf, fruit, and vegetable crops. In cotton, Palmer amaranth was listed as the most common and most troublesome weed (Van Wychen 2022). Morningglory species placed second on lists for most troublesome and most common weeds in cotton. Morningglory species also placed seventh on the most troublesome weeds among broadleaf crops, fruits, and vegetables. Goosegrass (*Eleusine indica* L.) was identified as the third most common and troublesome weed for cotton production and prickly sida

(*Sida spinosa* L.) was in the top five on both the most common and troublesome lists (Van Wychen 2022).

There have been many reports of herbicide-resistant Palmer amaranth in cotton production in the United States. These reports include resistance to acetolactate synthase inhibitors (Herbicide Resistance Action Committee (HRAC) Group 2), microtubule assembly inhibitors (HRAC Group 3), auxinic herbicides (HRAC Group 4), enolpyruvyl shikimate phosphate synthase inhibitors (HRAC Group 9), glutamine synthetase inhibitors (HRAC Group 10), protoporphyrinogen oxidase inhibitors (HRAC Group 14), and very long-chain fatty acid synthesis inhibitors (HRAC Group 15) (Heap 2022). In Texas cotton, weed resistance to HRAC Group 9 has been reported (Heap 2022), although there is concern about resistance to several other herbicides.

Cotton is an extremely important commodity crop in the United States and globally. Cotton accounts for 25% of fiber use globally (USDA-ERS 2022a). The United States accounts for approximately 35% of global cotton exports in recent years. Texas accounts for approximately 40% of domestic cotton production. In Texas, most of the cotton production occurs in the High Plains region due to the suitable climate (USDA-ERS 2022b), although weather extremes and other events can compromise cotton production.

Weeds have been an issue in cotton production as long as it has been cultivated. Many different approaches have been used to control common and troublesome weeds in cotton crops. When weeds are uncontrolled in cotton there can be negative impacts to the crop. Buchanan and Burns (1970) determined that cotton requires approximately an 8-week weed-free period at the beginning of the growing season for cotton to achieve maximum lint yield. After this 8-week period, cotton is sufficiently competitive to suppress weeds through competition (Buchanan and Burns 1970). Morgan et al. (2001) reported that Palmer amaranth when left to compete with cotton can reduce canopy volume by 35 and 45% 6 and 10 weeks after emergence, respectively. Cotton lint yield can be reduced linearly from 13 to 57% when 1 to 10 Palmer amaranth plants per 9.1 meters of row are present (Morgan et al. 2001). Rowland et al. (1999) observed that for each additional weed per 10 meters of row, yield could be reduced by 11.5% when weed densities are ≤8 weeds per 10 meters of row. Transgenic traits that allow for herbicide tolerance has created many options for control of troublesome weeds in cotton crops.

BXN™ (bromoxynil-resistant) was the first cotton herbicide resistance trait in the United States. The trait was deregulated in 1994 and was available for planting in 1995 (Vulchi et al. 2022). BXN™ cotton was tolerant to an over-the-top application of bromoxynil, which is phytotoxic to wildtype cotton (Vulchi et al. 2022). The introduction of this trait allowed a new weed control option for cotton growers, but the technology was not widely adopted due to bromoxynil not being a broad-spectrum herbicide (Vulchi et al., 2022).

BXN™ cotton was quickly less desirable when the next herbicide resistant technology, Roundup Ready®, came to market. Roundup Ready® cotton was deregulated in 1995 and allowed for applications of glyphosate during vegetative growth of cotton, but the fruiting stage was sensitive (Vulchi et al. 2022, Mills et al. 2008; Light et al. 2003). Applications of glyphosate in the first generation of this Roundup Ready® trait could not be made later than the four-leaf stage (May et al. 2004). Roundup Ready® Flex cotton was deregulated in 2004 and allowed for applications later in the growth and development of cotton. With this new trait, over-the-top applications could be made up until a week before harvest. Roundup® brand herbicides were the only glyphosate formulations labelled for application in Roundup Ready® and Roundup Ready® Flex cotton (Vulchi et al. 2022). In 2009, GlyTol® cotton was deregulated. GlyTol® cotton allowed for applications of any glyphosate formulation that was labelled for cotton (Vulchi et al. 2022). The rapid adoption of these technologies and widespread use of glyphosate created intense selection pressure that contributed to the evolution of glyphosate resistance in several weed species, including Palmer amaranth.

LibertyLink® cotton, deregulated in 2003, allowed for over-the-top applications of glufosinate-ammonium (Vulchi et al. 2002). This technology provided an alternative postemergence control option for *Amaranthus palmeri,* especially when glyphosate-resistant weeds are present (Culpepper et al. 2009; Vulchi et al. 2022). Adoption rates of this technology were relatively low due to the lack of a stacked technology with Roundup Ready®, which provided better control of most weeds that were not glyphosate-resistant (Culpepper et al. 2009).

The first case of stacking herbicide-resistant traits came when GlyTol®-LibertyLink® cotton was commercialized in 2011 (Vulchi et al. 2022). This allowed for glyphosate and glufosinate to be tank-mixed and sprayed over-the-top without crop safety issues (Vulchi et al. 2022); however, Reed et al. (2014) reported that tank mixes of glyphosate and glufosinate did not control Palmer amaranth as well as glyphosate alone. This would suggest that sequential applications of these herbicides would be a better option than applied in a tank-mixed application (Vulchi et al. 2022; Reed et al. 2014).

Bollguard II® XtendFlex® cotton, deregulated in 2015, was the first commercialized cotton that possessed a triple-stack herbicide package (Vulchi et al. 2022). Bollguard II® XtendFlex® cotton provided 10-fold resistance to normal field application rates of dicamba (Moser, 2007). This technology allowed for the use of dicamba applied preemergence and postemergence. This also gave growers another option to control glyphosate-resistant Palmer amaranth with alternative postemergence herbicides (Vulchi et al. 2022).

Enlist® cotton, deregulated in 2015, introduced another triple-stacked herbicide-tolerance option. Enlist® cotton provided resistance to 2,4-D, a synthetic auxin herbicide. The advantage of this trait is the ability to tank mix 2,4-D with glufosinate to control larger Palmer amaranth (Vulchi et al. 2022).

Isoxaflutole-resistant Axant™ Flex cotton was deregulated in the United States in 2018 but is not yet available for commercial production. This technology allows for the use of a novel herbicide in cotton, isoxaflutole. It is being evaluated in the United States for both preemergence and early-postemergence applications (Vulchi et al. 2022). This is the first quadruple stack herbicide technology to be introduced in cotton. Axant™ Flex cotton will provide the ability to apply isoxaflutole, glyphosate, glufosinate, and dicamba at-plant and in-season.

Isoxaflutole is a pigment inhibitor and works by preventing the biosynthesis of carotenoids. Carotenoids protect the chlorophyll from photooxidizing in sunlight (EPA 1998). Isoxaflutole is a HRAC Group 27 herbicide and belongs to the isoxazole family (WSSA 2021). Isoxaflutole targets 4-hydroxyphenylpyruvate dioxygenase (HPPD), which can lead to bleaching symptomology of susceptible plants. Isoxaflutole is converted to its diketonitrile derivative form in plants, which is the herbicidally active form (Pallett et al. 2001). Isoxaflutole was registered for use in field corn in 1998 (EPA 1998).

Isoxaflutole is a soil-active herbicide. The soil activity of applied herbicides is an important aspect of weed management programs in many different crops. The use of preemergence residual herbicides in Roundup Ready® soybean (*Glycine max* L.) can provide more consistent weed control, reduce the amount of and size of weeds present at the time of the postemergence application, and provide a larger window of postemergence application timing (Sprague 2006). Similar recommendations are made in cotton production. Cotton tends to have a slower seedling growth rate than most other crops; therefore, it is important to control weeds early-season to avoid competition for vital consumable environmental resources. Significant yield losses can occur if weeds are allowed to compete with seedling cotton.

The use of residual herbicides prior to or at planting can control weeds before they emerge, which can reduce the need for postemergence applications (McGinty et al. 2016). Preemergence control of Palmer amaranth with isoxaflutole tank-mix combinations with commercially available cotton residual herbicides was studied by Foster et al. (2021). They found that all isoxaflutole tank-mix partners controlled Palmer amaranth ≥92% 42 days after treatment. In College Station, Texas, all isoxaflutole tank-mix treatments provided ≥75% Palmer amaranth control 42 days after treatment. Isoxaflutole at 0.11 kg ai ha^{-1} plus fluridone at 0.17 kg ai ha^{-1} completely controlled Palmer amaranth 42 days after treatment (Foster et al. 2021).

Isoxaflutole-resistant soybean are already commercially available. Isoxaflutole-resistant cotton is not yet commercially available, but university research has been conducted for several years to evaluate crop response and identify effective weed management systems with this new technology. Foster et al. (2022) evaluated crop response and weed control in isoxaflutole-based cotton systems on the Texas High Plains. Crop response did not exceed 6% in New Deal, Texas, and did not exceed 14% at Lubbock, Texas in 2019 and 2020 and cotton lint yields did not differ from the nontreated weed-free control in any of the locations over two years (Foster et al. 2022).

Foster et al. (2022) also evaluated preemergence plus early-postemergence combinations that included isoxaflutole at Halfway, Texas. They found that control of Palmer amaranth was ≥94% for all treatments that included isoxaflutole 21 days after preemergence applications and concluded that the inclusion of isoxaflutole in cotton weed management systems can provide season-long control without negative affects to cotton lint yields or fiber quality. Joyner et al. (2022) evaluated cotton crop response following applications of isoxaflutole in combination with other cotton herbicides. Crop response following preemergence applications of isoxaflutole was minimal (0-3%). They also found that HPPD-resistant cotton was minimally injured by isoxaflutole applied preemergence and early-postemergence and tolerated standard cotton herbicides with no yield differences observed (Joyner et al. 2022). Farr et al. (2022) conducted similar studies and reported that crop response 14 days after preemergence treatments did not exceed 6% for all treatments, including those that contained isoxaflutole.

There are two cases of resistance to isoxaflutole worldwide, *Raphanus raphanistrum* in Australian wheat and *Amaranthus tuberculatus* in corn and soybean in the United States (Heap 2023). There are more cases of Group 27 herbicide resistance worldwide, but in the United States two species have been identified to have resistance to Group 27 herbicides, *Amaranthus tuberculatus* and *Amaranthus palmeri* (Heap 2023). For long-term sustainability of this herbicide, isoxaflutole must be used as part of a herbicide system that contains other herbicide modes of action.

The use of HPPD-inhibiting herbicides in cotton production would provide another mode of action to help control troublesome weeds and could be an important part of future cotton weed management programs. With recent developments of resistance in Palmer amaranth to several postemergence herbicides, the need for effective residual weed control has increased. The addition of a new mode of action to cotton weed management will provide more options to alternate modes of action within season and across seasons.

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CHAPTER II

CROP RESPONSE AND PALMER AMARANTH CONTROL IN AXANT™ FLEX COTTON ON THE TEXAS HIGH PLAINS

M. E. Smith, P. A. Dotray, and A. C. Hixson

ABSTRACT

Axant™ Flex cotton is the first quadruple-stacked herbicide technology in cotton that allows the use of a herbicide novel to cotton. Isoxaflutole is an HPPD-inhibiting herbicide that will aid in the control of troublesome weeds in cotton. Axant™ Flex cotton herbicide trials were conducted near New Deal, Texas in 2021 and 2022. The objective was to evaluate Axant™ Flex cotton response and Palmer amaranth control in herbicide systems that included isoxaflutole. Crop density, visual crop response, weed control, weed density, and lint yield were assessed. Crop response never exceeded 13% in either year. Visual crop response was greater in 2021 than in 2022, possibly due to greater early-season rainfall in 2021. Preemergence treatments that included isoxaflutole provided ≥87% Palmer amaranth control 29 days after application in both years. Isoxaflutole plus fluridone was one of the best preemergence treatments in both years and provided 97 and 93% Palmer amaranth control in 2021 and 2022, respectively. When isoxaflutole at 0.11 kg ai ha^{-1} was used preemergence, Palmer amaranth control was ≥95% 14 days after early-postemergence applications in 2021. All treatments that included isoxaflutole preemergence controlled Palmer amaranth ≥92% 14 days after early-postemergence applications. Isoxaflutole plus fluometuron followed by (fb) glufosinate plus glyphosate plus dimethenamid-P was the only treatment that controlled Palmer amaranth ≥90% 28 days after the early-postemergence application in both years.

Isoxaflutole plus fluridone fb dicamba plus glyphosate plus dimethenamid-P was the only treatment that controlled Palmer amaranth ≥90% at the end of the season. Lint yield ranged from 1,471 to 1,650 kg lint ha^{-1} in 2021 and 1,594 to 2,272 kg lint ha^{-1} in 2022, and all treatments yielded greater than the nontreated control. Axant™ Flex cotton will allow the use of isoxaflutole, which will provide a new tool for controlling troublesome weeds at-plant and in-crop.

Nomenclature: Palmer amaranth, *Amaranthus palmeri* S. Wats.

Key Words: isoxaflutole, weed control, Axant™ Flex cotton

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is an important commodity in the United States and was planted on 5.6 million hectares in 2022 and Texas accounted for 3.2 million of those hectares (USDA-NASS 2023). On average, 1.6 million hectares of cotton are planted annually on the Texas High Plains and this region is responsible for producing an average of 3.7 million bales of cotton per year (Plains Cotton Growers 2023). Cotton management in this region experiences many challenges every year. Limited rainfall and irrigation are often issues producers encounter on the Texas High Plains, but weeds also pose a major challenge. Management of weeds is crucial for crops to maximize growth. It is estimated that weeds cause 36% yield loss in cotton worldwide (Oerke 2006).

Palmer amaranth (*Amaranthus palmeri* S. Wats.) is a dioecious, summer annual broadleaf weed that is native in the southwestern United States but has spread across the country (USDA-NRCS 2017). In a survey conducted in 2022, Palmer amaranth was identified as the most common and most troublesome weed in cotton production in the United States (Van Wychen 2022). Palmer amaranth can reduce yields and harvest complications if poorly controlled and allowed to compete with cotton (Morgan et al. 2001). Plants left uncontrolled and allowed to produce seed can quickly add to the weed seed soil bank. Female Palmer amaranth plants produce an average of 400,000 seed per plant (Sosnoskie 2018).

Prior to widespread adoption of transgenic crops, weed management in cotton relied heavily on soil residual herbicides (Young 2006). Trifluralin and fluometuron were applied to 50% and 25% of cotton hectares, respectively (Young 2006). After the introduction of glyphosate-resistant cotton in 1997, glyphosate use increased rapidly, and by 2000 replaced trifluralin as the herbicide applied to the most cotton hectares (Young 2006). Glyphosate-resistant Palmer amaranth in cotton was first identified in the United States in 2005 in Georgia and North Carolina (Heap 2023). In 2011, the first case of glyphosate-resistant Palmer amaranth was identified in Texas cotton (Heap 2023). Glufosinate-resistant (LibertyLink®) cotton, deregulated in 2003 (Vulchi et al. 2022), provides another option for postemergence weed control in-crop. Reed et al. (2014) observed antagonism with glyphosate plus glufosinate tank-mix combinations compared to glyphosate or glufosinate alone and observed greater control with glyphosate alone.

Dicamba-resistant (XtendFlex®) and 2,4-D-resistant (Enlist®) cotton, both HRAC Group 4 herbicides, were deregulated in 2015 and provide additional postemergence options to control troublesome weeds (Vulchi et al. 2022). In 2020, the first case of dicamba-resistant Palmer amaranth in cotton was identified in Tennessee (Heap 2023). More control options for troublesome weeds in cotton are needed to slow the development of herbicide resistance.

Axant™ Flex cotton from BASF introduces the first quadruple-stack herbicide package in cotton (BASF 2023). Axant™ Flex cotton is resistant to glyphosate, glufosinate, dicamba, and isoxaflutole (BASF 2023). Isoxaflutole belongs to HRAC Group 27, the 4-hydroxyphenylpyruvate dioxygenase (HPPD)-inhibiting class of herbicides. Isoxaflutole was originally registered in 1998 for use in field corn (EPA 1998).

Isoxaflutole tank-mix treatments have been reported to provide ≥92% control of Palmer amaranth 42 days after application (Foster et al. 2021). Isoxaflutole has been reported to control troublesome weeds with minimal visual crop response and no yield or fiber quality differences in isoxaflutole-tolerant cotton were observed (Foster et al. 2022; Joyner et al. 2022; Farr et al. 2022). Isoxaflutole has the potential to increase and extend preemergence weed control when used with other commercially available cotton soil-residual herbicides. The objective of this research was to evaluate crop response and control of Palmer amaranth in Axant™ Flex cotton using isoxaflutole.

MATERIALS AND METHODS

Field studies were conducted at the Texas Tech University New Deal Research Farm near New Deal, Texas (33.73098 N, -101.73378 W) in 2021 and 2022. This location is equipped with subsurface drip irrigation and the soil type was a Pullman clay loam (52% sand, 16% silt, 32% clay) with a pH of 7.5 and less than 1% organic matter. Axant™ Flex cotton was planted at 128,700 seeds ha^{-1} on May 25, 2021, and May 18, 2022. A rod-weeder was used immediately prior to planting to provide a weed-free seedbed. Plot size was 4.1 by 7.6 meters with 102-centimeter row spacing. Treatments were arranged in a randomized complete block design (RCBD) with four replications. Irrigation was applied at 265 and 375 mm and total in-season rainfall was 310 and 346 mm in 2021 and 2022, respectively. All treatments received 44.8 and 39.2 kg nitrogen ha^{-1} in 2021 and 2022, respectively, using urea ammonium nitrate (32-0-0) liquid fertilizer applied through the subsurface drip irrigation.

Trifluralin at 1.12 kg ai ha^{-1} was applied preplant across the entire area including the nontreated in 2021. Pendimethalin at 1.07 kg ai ha^{-1} was applied preplant to all treatments including the nontreated in 2022. These treatments were incorporated twice in opposite directions at a depth of 5 centimeters using a rolling cultivator within an hour of application.

Preemergence (PRE) treatments were applied on May 25, 2021 (Table 2.1) and May 18, 2022 (Table 2.2). All treatments were applied with a CO_2-pressurized backpack sprayer at 140 L ha^{-1}. All non-dicamba preemergence treatments were applied with AIXR 11002 nozzles (TeeJet® Technologies, Glendale Heights, IL) and all dicamba-containing treatments were applied with TTI 11002 nozzles (TeeJet® Technologies, Glendale Heights, IL). Early-postemergence (EPOST) treatments were applied using the same nozzle scheme on June 22, 2021 (Table 2.1) and June 16, 2022 (Table 2.2). All dicamba-containing treatments included potassium carbonate at 0.41 kg ai ha^{-1}. All glufosinate-containing treatments included ammonium sulfate at 3.36 kg ha^{-1}.

Cotton density was evaluated 7 days after emergence from two meters of row from two locations in the center two rows of each plot. Visual crop response (stunt, chlorosis, necrosis) was rated on a 0-100% scale with 0% being no visual damage and 100% being complete plant death (Frans et al. 1986). Crop response was recorded 7 and 14 days after emergence, and 7, 14, and 21 days after the EPOST application. Weed control was evaluated on a 0-100% scale with 0% being no weeds controlled and 100% being all weeds controlled when compared to the nontreated check (Frans et al. 1986). Palmer amaranth control was evaluated at the time of the EPOST application (29 days after PRE) and 14 and 28 days after EPOST. Final Palmer amaranth control was evaluated at the end of the growing season at the time of the first harvest aid application. Weed density was determined at the time of the EPOST application and 14 and 28 days after EPOST using $0.25m^2$ quadrats from two locations within the center two rows of each plot.

In 2021 and 2022, two harvest aid applications were made. Ethephon at 1.68 kg ai ha^{-1} plus cyclanilide at 0.105 kg ai ha^{-1} and thidiazuron at 0.193 kg ai ha^{-1} plus crop oil concentrate at 1% v/v was applied on October 7, 2021, and October 13, 2022. Paraquat at 0.56 kg ai ha^{-1} plus a nonionic surfactant at 0.25% v/v was applied on October 14, 2021, and October 27, 2022. Cotton was harvested using a John Deere 7445 cotton stripper with onboard scales to weigh seed cotton per plot. Grab samples were collected to determine lint turnout. Lint turnout was determined using a 20-saw table-top gin at the BASF Trait and Development station in Lubbock, Texas. Lint yield per plot was determined by multiplying the seed cotton weight per plot by the lint turnout.

Analysis of variance was conducted using the GLIMMIX procedure in SAS (version 9.4; SAS Institute Inc., Cary, NC). Means separation was analyzed using Fisher's least significant difference (LSD) at $\alpha=0.05$ for all analyses.

RESULTS AND DISCUSSION

The 2021 and 2022 growing seasons were very different. Rainfall was common at and after planting in 2021 but not in 2022. Rainfall in 2022 came at the end of the season near harvest. Cotton density was not different among treatments 7 days after crop emergence in 2021 and 2022 (Table 2.2). No differences were observed in crop response 14 days after PRE applications in 2021 and 2022 and injury was ≤3% in 2021 and 1% in 2022 (Table 2.3). Crop response 21 days after PRE applications ranged from 3-8% for all treatments in 2021 (Table 2.4). No crop response was observed 21 days after PRE applications in 2022. Crop response in 2021 was ≤13% for all treatments and was ≤6% for all treatments that included isoxaflutole in the EPOST application (Table 2.5).

In 2021, early-season rainfall promoted dense flushes of Palmer amaranth. Palmer amaranth density in the nontreated control plots was 699,000 plants ha^{-1} 29 days after PRE applications (Table 2.7). Palmer amaranth was controlled ≥91% following all PRE applications that included isoxaflutole. Palmer amaranth was controlled ≥97% following isoxaflutole plus fluridone, isoxaflutole plus fluometuron, and isoxaflutole plus acetochlor (Table 2.7). All PRE applications that did not include isoxaflutole controlled Palmer amaranth ≤84%. Palmer amaranth was controlled 84% following acetochlor plus fluometuron and 62% following fluometuron (Table 2.7). Preemergence treatments that included isoxaflutole had ≤5,000 plants ha^{-1} Palmer amaranth densities whereas treatments that did not include isoxaflutole had Palmer amaranth densities ranging from 8,000 to 158,000 plants ha^{-1} (Table 2.7).

In 2022, reduced rainfall early-season limited Palmer amaranth emergence. Palmer amaranth density in nontreated control plots was 333,000 plants ha^{-1} (Table 2.7). Treatments that included isoxaflutole in the PRE application controlled Palmer amaranth ≥87% 29 days after application. Palmer amaranth was controlled 93% following isoxaflutole plus fluridone (Table 2.7). Treatments that did not include isoxaflutole controlled Palmer amaranth ≤79%. Palmer amaranth was controlled 79% following acetochlor plus fluometuron and pendimethalin plus fluometuron and 64% following fluometuron and fluridone (Table 2.7).

Palmer amaranth was controlled ≥81% following all treatments 14 days after EPOST application in 2021 (Table 2.8). Treatments that included the full field rate of isoxaflutole (0.11 kg ai ha^{-1}) in the PRE application controlled Palmer amaranth ≥95% 14 days after EPOST application regardless of the EPOST treatment applied (Table 2.8). All dicamba-containing EPOST treatments controlled Palmer amaranth ≥81% 14 days after treatment (Table 2.8). Isoxaflutole plus pendimethalin followed by (fb) dicamba plus glyphosate plus dimethenamid-P controlled Palmer amaranth 97% at this timing (Table 2.8). Glufosinate-containing EPOST treatments controlled Palmer amaranth ≥90%. Isoxaflutole plus fluometuron fb glufosinate plus glyphosate plus dimethenamid-P and fluometuron plus pendimethalin fb glufosinate plus glyphosate plus isoxaflutole controlled Palmer amaranth 97% (Table 2.8). When two modes of action were used in the PRE application, glufosinate-containing EPOST applications provided ≥96% control of Palmer amaranth 14 days after application (Table 2.8). Isoxaflutole plus fluridone fb dicamba plus glyphosate plus dimethenamid-P and isoxaflutole plus dicamba fb glufosinate plus glyphosate plus dimethenamid-P limited Palmer amaranth densities to ≤70,000 weeds ha^{-1} (Table 2.8). When isoxaflutole was included as a residual in the EPOST application, Palmer amaranth was controlled ≥86%. Fluometuron plus pendimethalin fb glufosinate plus glyphosate plus isoxaflutole controlled Palmer amaranth 97% (Table 2.8).

Palmer amaranth density was 270,000 weeds ha^{-1} in the nontreated control plots and ≤55,000 weeds ha^{-1} for all treated plots (Table 2.8). Palmer amaranth was controlled ≥86% 14 days after the EPOST application (Table 2.8). Palmer amaranth control was ≥92% 14 days after EPOST for all treatments that included isoxaflutole in the PRE application (Table 2.8). Dicamba-containing EPOST treatments controlled Palmer amaranth ≥86% while glufosinate-containing EPOST treatments controlled Palmer amaranth ≥88% 14 days after application (Table 2.8). When multiple modes of action were used in the PRE application, dicamba-containing EPOST treatments provided ≥91%

Palmer amaranth control (Table 2.8). When multiple modes of action were used in the PRE application, glufosinate-containing EPOST treatments controlled Palmer amaranth ≥93% 14 days after application (Table 2.8). Isoxaflutole plus fluridone fb dicamba plus glyphosate plus dimethenamid-P controlled Palmer amaranth 97% and isoxaflutole plus fluometuron fb glufosinate plus glyphosate plus dimethenamid-P controlled Palmer amaranth 98% (Table 2.8). When isoxaflutole was used as a residual in the EPOST application Palmer amaranth was controlled ≥91%.

Only two treatments provided greater than 90% Palmer amaranth control 28 days after the EPOST application in 2021. Isoxaflutole plus pendimethalin fb dicamba plus glyphosate plus dimethenamid-P (93%) and isoxaflutole plus fluometuron fb glufosinate plus glyphosate plus dimethenamid-P (91%) (Table 2.9). All treatments that included isoxaflutole in the PRE application controlled Palmer amaranth ≥88% 28 days after application regardless of the EPOST treatment used. In 2022, several treatments provided ≥90% Palmer amaranth control 28 days after EPOST application (Table 2.9). All treatments that included isoxaflutole in the PRE treatment controlled Palmer amaranth ≥89% 28 days after EPOST application regardless of the EPOST treatment used (Table 2.9). Isoxaflutole plus fluridone fb dicamba plus glyphosate plus dimethenamid-P controlled Palmer amaranth 95% and isoxaflutole plus fluometuron fb glufosinate plus glyphosate plus dimethenamid-P controlled Palmer amaranth 96% (Table 2.9).

End of season Palmer amaranth control was ≥80% and ≥69% for all treatments in 2021 and 2022, respectively (Table 2.10). The only treatment that controlled Palmer amaranth >90% at the end of the season in both years was isoxaflutole plus fluridone fb dicamba plus glyphosate plus dimethenamid-P (Table 2.10). All treatments that received a full rate of isoxaflutole in a single application (PRE or EPOST) resulted in ≥84% and ≥71% Palmer amaranth control at the end of the season in 2021 and 2022, respectively (Table 2.10).

In 2021, lint yield ranged from 1,471 to 1,650 kg ha^{-1} (Table 2.11). The only difference in yield in 2021 was following isoxaflutole fb dicamba plus glyphosate plus dimethenamid-P, which was greater than isoxaflutole plus fluometuron fb dicamba plus glyphosate plus dimethenamid-P, acetochlor plus fluometuron fb dicamba plus glyphosate plus acetochlor, and isoxaflutole plus fluometuron fb glufosinate plus glyphosate plus dimethenamid-P (Table 2.11). In 2022, lint yield ranged from 1,594 to 2,272 kg ha^{-1} (Table 2.11). Differences in lint yield were observed following isoxaflutole plus fluridone fb dicamba plus glyphosate plus dimethenamid-P and isoxaflutole plus fluometuron fb glufosinate plus glyphosate plus dimethenamid-P, which were greater than following acetochlor plus fluometuron fb dicamba plus glyphosate plus acetochlor, isoxaflutole fb dicamba plus glyphosate plus dimethenamid-P, fluometuron plus pendimethalin fb glufosinate plus glyphosate plus isoxaflutole, and fluometuron fb glufosinate plus glyphosate plus dimethenamid-P (Table 2.11). Lint yield following isoxaflutole plus pendimethalin fb dicamba plus glyphosate plus dimethenamid-P, fluometuron fb dicamba plus glyphosate plus dimethenamid-P, and isoxaflutole (0.07 kg ai ha^{-1}) plus fluometuron fb dicamba plus glyphosate plus isoxaflutole (0.07 kg ai ha^{-1}) were greater than yield following fluometuron fb glufosinate plus glyphosate plus dimethenamid-P (Table 2.11).

SUMMARY

The addition of a new herbicide mode of action to cotton production systems will provide weed managers with a new tool to aid in the control of troublesome weeds, specifically glyphosate-resistant Palmer amaranth. Isoxaflutole will improve preemergence control of Palmer amaranth when used with other soil residual herbicides. When isoxaflutole was used in glufosinate-based systems, Palmer amaranth control was as effective as dicamba-based systems. This could be very useful as reports of dicamba-resistant Palmer amaranth may be occurring in cotton fields in other states (Heap 2023). In this research, treatments such as isoxaflutole plus fluridone fb dicamba plus glyphosate plus dimethenamid-P and isoxaflutole plus fluometuron fb glufosinate plus glyphosate plus dimethenamid-P were effective at controlling Palmer amaranth season-long. Axant™ Flex cotton will increase management options to control troublesome weeds in-crop.

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Table 2.1. Herbicides, treatments, rates, and application timing used in 2021 and 2022.

Treatments	Rate	Application timing[a]
	kg ai or ae ha^{-1}	
Nontreated control	--	--
Isoxaflutole+pendimethalin	0.11+1.07	PRE
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST
Isoxaflutole+fluridone	0.11+0.25	PRE
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST
Isoxaflutole+fluometuron	0.11+1.12	PRE
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST
Isoxaflutole+acetochlor	0.11+1.26	PRE
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST
Pendimethalin+fluometuron	1.07+1.12	PRE
Dicamba+glyphosate+isoxaflutole	0.56+1.26+0.11	EPOST
Acetochlor+fluometuron	1.26+1.12	PRE
Dicamba+glyphosate+acetochlor	0.56+1.26+1.26	EPOST
Fluometuron	1.12	PRE
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST
Fluridone	0.25	PRE
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST
Isoxaflutole	0.11	PRE
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST
Isoxaflutole+fluometuron	0.05+0.25	PRE
Dicamba+glyphosate+isoxaflutole	0.56+1.26+0.05	EPOST
Isoxaflutole+fluometuron	0.11+1.12	PRE
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST
Isoxaflutole+dicamba	0.11+0.56	PRE
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST
Fluometuron+pendimethalin	1.12+1.07	PRE
Glufosinate+glyphosate+isoxaflutole	0.88+1.26+0.11	EPOST
Fluometuron	1.12	PRE
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST

[a] Abbreviations: PRE, preemergence; EPOST, early-postemergence.

Table 2.2. Cotton density 14 days after planting in 2021 and 2022 in Axant™ Flex cotton systems.

		Cotton density	
Preemergence Treatments[a]	Rate	2021	2022
	kg ai or ae ha^{-1}	-----------1,000 plants ha^{-1}-----------	
Nontreated control		123	87
Isoxaflutole+pendimethalin	0.11+1.07	104	95
Isoxaflutole+fluridone	0.11+0.25	115	85
Isoxaflutole+fluometuron	0.11+1.12	121	90
Isoxaflutole+acetochlor	0.11+1.26	123	84
Pendimethalin+fluometuron	1.07+1.12	119	89
Acetochlor+fluometuron	1.26+1.12	126	90
Fluometuron	1.12	120	90
Fluridone	0.25	128	93
Isoxaflutole	0.11	123	90
Isoxaflutole+fluometuron	0.07+1.12	118	86
Isoxaflutole+dicamba	0.11+0.56	121	80

Table 2.3. Crop response 14 days after preemergence application in 2021 and 2022 in Axant™ Flex cotton systems.

		Crop response	
Preemergence Treatments[a]	Rate	2021	2022
	kg ai or ae ha^{-1}	------------------%------------------	
Nontreated control		0	0
Isoxaflutole+pendimethalin	0.11+1.07	0	0
Isoxaflutole+fluridone	0.11+0.25	1	0
Isoxaflutole+fluometuron	0.11+1.12	0	0
Isoxaflutole+acetochlor	0.11+1.26	0	0
Pendimethalin+fluometuron	1.07+1.12	0	0
Acetochlor+fluometuron	1.26+1.12	0	0
Fluometuron	1.12	1	0
Fluridone	0.25	3	1
Isoxaflutole	0.11	0	0
Isoxaflutole+fluometuron	0.07+1.12	0	0
Isoxaflutole+dicamba	0.11+0.56	0	0

Table 2.4. Crop response 21 days after preemergence application in 2021 and 2022 in Axant™ Flex cotton systems.

Preemergence Treatments[a]	Rate	Crop response[a]	
		2021	2022
	kg ai or ae ha^{-1}	------------------%------------------	
Nontreated control		0d	0
Isoxaflutole+pendimethalin	0.11+1.07	3cd	0
Isoxaflutole+fluridone	0.11+0.25	8abc	0
Isoxaflutole+fluometuron	0.11+1.12	9a	0
Isoxaflutole+acetochlor	0.11+1.26	4bc	0
Pendimethalin+fluometuron	1.07+1.12	9a	0
Acetochlor+fluometuron	1.26+1.12	5abc	0
Fluometuron	1.12	8ab	0
Fluridone	0.25	4bc	0
Isoxaflutole	0.11	5abc	0
Isoxaflutole+fluometuron	0.07+1.12	7abc	0
Isoxaflutole+dicamba	0.11+0.56	9a	0

[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at $P < 0.05$.

Table 2.5. Crop response 7 days after early-postemergence application in 2021 and 2022 in Axant™ Flex cotton systems.

			Crop response[b]	
Treatments	Rate	Application timing[a]	2021	2022
	kg ai or ae ha^{-1}		--------------------%--------------------	
Nontreated control	--	--	0d	0f
Isoxaflutole+pendimethalin dicamba+glyphosate+dimethenamid-P	0.11+1.07 0.56+1.26+0.67	PRE EPOST	9abc	6bcd
Isoxaflutole+fluridone Dicamba+glyphosate+dimethenamid-P	0.11+0.25 0.56+1.26+0.67	PRE EPOST	5cd	5cde
Isoxaflutole+fluometuron Dicamba+glyphosate+dimethenamid-P	0.11+1.12 0.56+1.26+0.67	PRE EPOST	13a	5cde
Isoxaflutole+acetochlor Dicamba+glyphosate+dimethenamid-P	0.11+1.26 0.56+1.26+0.67	PRE EPOST	9abc	5cde
Pendimethalin+fluometuron Dicamba+glyphosate+isoxaflutole	1.07+1.12 0.56+1.26+0.11	PRE EPOST	6bc	3ef
Acetochlor+fluometuron Dicamba+glyphosate+acetochlor	1.26+1.12 0.56+1.26+1.26	PRE EPOST	9abc	8abc
Fluometuron Dicamba+glyphosate+dimethenamid-P	1.12 0.56+1.26+0.67	PRE EPOST	6bc	4de

Table 2.5 Continued

Fluridone	0.25	PRE	5cd	5cde
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST		
Isoxaflutole	0.11	PRE	5cd	5cde
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST		
Isoxaflutole+fluometuron	0.05+0.25	PRE	4cd	3ef
Dicamba+glyphosate+isoxaflutole	0.56+1.26+0.05	EPOST		
Isoxaflutole+fluometuron	0.11+1.12	PRE	11ab	9ab
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST		
Isoxaflutole+dicamba	0.11+0.56	PRE	12a	10a
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST		
Fluometuron+pendimethalin	1.12+1.07	PRE	5cd	10a
Glufosinate+glyphosate+isoxaflutole	0.88+1.26+0.11	EPOST		
Fluometuron	1.12	PRE	9abc	9ab
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST		

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[a] Abbreviations: PRE, preemergence; EPOST, early-postemergence.

[b] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at $P < 0.05$.

Table 2.6. Crop response 14 days after early-postemergence application in 2021 and 2022 in Axant™ Flex cotton systems.

Treatments	Rate	Application timing[a]	Crop response[b]	
			2021	2022
	kg ai or ae ha^{-1}		--------------------%--------------------	
Nontreated control	--	--	0d	0b
Isoxaflutole+pendimethalin Dicamba+glyphosate+dimethenamid-P	0.11+1.07 0.56+1.26+0.67	PRE EPOST	4.25abc	5a
Isoxaflutole+fluridone Dicamba+glyphosate+dimethenamid-P	0.11+0.25 0.56+1.26+0.67	PRE EPOST	3.5bc	5a
Isoxaflutole+fluometuron Dicamba+glyphosate+dimethenamid-P	0.11+1.12 0.56+1.26+0.67	PRE EPOST	4.25abc	5a
Isoxaflutole+acetochlor Dicamba+glyphosate+dimethenamid-P	0.11+1.26 0.56+1.26+0.67	PRE EPOST	3.5bc	3.75a
Pendimethalin+fluometuron Dicamba+glyphosate+isoxaflutole	1.07+1.12 0.56+1.26+0.11	PRE EPOST	3bc	1.25b
Acetochlor+fluometuron Dicamba+glyphosate+acetochlor	1.26+1.12 0.56+1.26+1.26	PRE EPOST	5ab	5a
Fluometuron Dicamba+glyphosate+dimethenamid-P	1.12 0.56+1.26+0.67	PRE EPOST	4.25abc	5a

Table 2.6 Continued

Fluridone	0.25	PRE	3.5bc	5a
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST		
Isoxaflutole	0.11	PRE	2cd	3.75a
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST		
Isoxaflutole+fluometuron	0.05+0.25	PRE	4.25abc	0b
Dicamba+glyphosate+isoxaflutole	0.56+1.26+0.05	EPOST		
Isoxaflutole+fluometuron	0.11+1.12	PRE	4.25abc	5a
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST		
Isoxaflutole+dicamba	0.11+0.56	PRE	4.25abc	5a
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST		
Fluometuron+pendimethalin	1.12+1.07	PRE	6.25a	5a
Glufosinate+glyphosate+isoxaflutole	0.88+1.26+0.11	EPOST		
Fluometuron	1.12	PRE	4.25abc	5a
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST		

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[a] Abbreviations: PRE, preemergence; EPOST, early-postemergence.

[b] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at $P < 0.05$.

Table 2.7. Palmer amaranth control and density 29 days after preemergence application in 2021 and 2022 in Axant™ Flex cotton systems.

		Palmer amaranth[b]			
		2021		2022	
PRE Treatments[a]	Rate	Control	Density	Control	Density
	kg ai or ae ha^{-1}	---------%---------	-1,000 plants ha^{-1}-	---------%---------	-1,000 plants ha^{-1}-
Nontreated control	--	0e	699a	0d	333a
Isoxaflutole+pendimethalin	0.11+1.07	96ab	0c	89a	78b
Isoxaflutole+fluridone	0.11+0.25	97a	0c	93a	38b
Isoxaflutole+fluometuron	0.11+1.12	97a	5c	92a	28b
Isoxaflutole+acetochlor	0.11+1.26	97a	0c	91a	53b
Pendimethalin+fluometuron	1.07+1.12	82c	53c	79b	100b
Acetochlor+fluometuron	1.26+1.12	84bc	18c	79b	63b
Fluometuron	1.12	62d	158b	64c	235a
Fluridone	0.25	80c	8c	64c	103b
Isoxaflutole	0.11	94ab	0c	88a	58b
Isoxaflutole+fluometuron	0.07+1.12	91abc	0c	91a	88b
Isoxaflutole+dicamba	0.11+0.56	91abc	0c	87a	103b

[a] Abbreviations: PRE; preemergence.

[b] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at $P < 0.05$.

Table 2.8. Palmer amaranth control and density 14 days after early-postemergence application in 2021 and 2022 in Axant™ Flex cotton systems.

			Palmer amaranth[b]			
			2021		2022	
Treatments	Rate	Timing[a]	Control	Density	Control	Density
	kg ai or ae ha^{-1}		-----%-----	1,000 ha^{-1}	-----%-----	1,000 ha^{-1}
Nontreated control	--	--	0d	2,060a	0g	270a
Isoxaflutole+pendimethalin Dicamba+glyphosate+dimethenamid-P	0.11+1.07 0.56+1.26+0.67	PRE EPOST	97a	80d	94a-d	20cde
Isoxaflutole+fluridone Dicamba+glyphosate+dimethenamid-P	0.11+0.25 0.56+1.26+0.67	PRE EPOST	95a	50d	97a	20cde
Isoxaflutole+fluometuron Dicamba+glyphosate+dimethenamid-P	0.11+1.12 0.56+1.26+0.67	PRE EPOST	96a	75d	96ab	10de
Isoxaflutole+acetochlor Dicamba+glyphosate+dimethenamid-P	0.11+1.26 0.56+1.26+0.67	PRE EPOST	95a	180bcd	95abc	20cde
Pendimethalin+fluometuron Dicamba+glyphosate+isoxaflutole	1.07+1.12 0.56+1.26+0.11	PRE EPOST	92ab	250bcd	91cde	25cde
Acetochlor+fluometuron Dicamba+glyphosate+acetochlor	1.26+1.12 0.56+1.26+1.26	PRE EPOST	92ab	250bcd	93b-e	15cde
Fluometuron Dicamba+glyphosate+dimethenamid-P	1.12 0.56+1.26+0.67	PRE EPOST	81c	495bc	90def	25cde

Table 2.8 Continued

Fluridone	0.25	PRE	95a	130cd	86f	40bc
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST				
Isoxaflutole	0.11	PRE	94a	160bcd	92b-e	40bc
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST				
Isoxaflutole+fluometuron	0.05+0.25	PRE	86bc	510b	95abc	30bcd
Dicamba+glyphosate+isoxaflutole	0.56+1.26+0.05	EPOST				
Isoxaflutole+fluometuron	0.11+1.12	PRE	97a	75d	98a	0e
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST				
Isoxaflutole+dicamba	0.11+0.56	PRE	96a	70d	96ab	20cde
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST				
Fluometuron+pendimethalin	1.12+1.07	PRE	97a	140bcd	93b-e	25cde
Glufosinate+glyphosate+isoxaflutole	0.88+1.26+0.11	EPOST				
Fluometuron	1.12	PRE	90ab	270bcd	88ef	55b
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST				

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[a] Abbreviations: PRE; preemergence; EPOST, early-postemergence.

[b] Means within a column followed by the same letter are not significantly different according to Fisher’s Protected LSD at $P < 0.05$.

Table 2.9. Palmer amaranth control and density 28 days after early-postemergence application in 2021 and 2022 in Axant™ Flex cotton systems.

			Palmer amaranth[b]			
			2021		2022	
Treatments	Rate	Timing[a]	Control	Density	Control	Density
	kg ai or ae ha^{-1}		-----%-----	1,000 ha^{-1}	-----%-----	1,000 ha^{-1}
Nontreated control	--	--	0e	765a	0g	185a
Isoxaflutole+pendimethalin Dicamba+glyphosate+dimethenamid-P	0.11+1.07 0.56+1.26+0.67	PRE EPOST	93a	100c	90b-e	25cd
Isoxaflutole+fluridone Dicamba+glyphosate+dimethenamid-P	0.11+0.25 0.56+1.26+0.67	PRE EPOST	88ab	110c	95ab	5e
Isoxaflutole+fluometuron Dicamba+glyphosate+dimethenamid-P	0.11+1.12 0.56+1.26+0.67	PRE EPOST	89ab	165bc	94abc	15de
Isoxaflutole+acetochlor Dicamba+glyphosate+dimethenamid-P	0.11+1.26 0.56+1.26+0.67	PRE EPOST	89ab	180bc	94abc	10de
Pendimethalin+fluometuron Dicamba+glyphosate+isoxaflutole	1.07+1.12 0.56+1.26+0.11	PRE EPOST	85abc	205bc	88de	35c
Acetochlor+fluometuron Dicamba+glyphosate+acetochlor	1.26+1.12 0.56+1.26+1.26	PRE EPOST	71d	385b	93a-d	15de
Fluometuron Dicamba+glyphosate+dimethenamid-P	1.12 0.56+1.26+0.67	PRE EPOST	75cd	190bc	89cde	15de

Table 2.9 Continued

Fluridone	0.25	PRE	78bcd	165bc	90b-e	15de
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST				
Isoxaflutole	0.11	PRE	89ab	135bc	89cde	20cde
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST				
Isoxaflutole+fluometuron	0.05+0.25	PRE	89ab	350bc	94abc	10de
Dicamba+glyphosate+isoxaflutole	0.56+1.26+0.05	EPOST				
Isoxaflutole+fluometuron	0.11+1.12	PRE	91a	140bc	96a	5e
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST				
Isoxaflutole+dicamba	0.11+0.56	PRE	88ab	150bc	92a-e	15de
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST				
Fluometuron+pendimethalin	1.12+1.07	PRE	76cd	335bc	86e	25cd
Glufosinate+glyphosate+isoxaflutole	0.88+1.26+0.11	EPOST				
Fluometuron	1.12	PRE	71d	205bc	79f	55b
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST				

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[a] Abbreviations: PRE; preemergence; EPOST, early-postemergence.

[b] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at $P < 0.05$.

Table 2.10. Palmer amaranth control at timing of first defoliation application in 2021 and 2022 in Axant™ Flex cotton systems.

Treatments	Rate	Application timing[a]	Palmer amaranth control[b] 2021	Palmer amaranth control[b] 2022
	kg ai or ae ha^{-1}		--------------------%--------------------	
Nontreated control	--	--	0e	0d
Isoxaflutole+pendimethalin Dicamba+glyphosate+dimethenamid-P	0.11+1.07 0.56+1.26+0.67	PRE EPOST	97a	89ab
Isoxaflutole+fluridone Dicamba+glyphosate+dimethenamid-P	0.11+0.25 0.56+1.26+0.67	PRE EPOST	92ab	94a
Isoxaflutole+fluometuron Dicamba+glyphosate+dimethenamid-P	0.11+1.12 0.56+1.26+0.67	PRE EPOST	89a-d	90ab
Isoxaflutole+acetochlor Dicamba+glyphosate+dimethenamid-P	0.11+1.26 0.56+1.26+0.67	PRE EPOST	92ab	86ab
Pendimethalin+fluometuron Dicamba+glyphosate+isoxaflutole	1.07+1.12 0.56+1.26+0.11	PRE EPOST	85bcd	88ab
Acetochlor+fluometuron Dicamba+glyphosate+acetochlor	1.26+1.12 0.56+1.26+1.26	PRE EPOST	81cd	90ab
Fluometuron Dicamba+glyphosate+dimethenamid-P	1.12 0.56+1.26+0.67	PRE EPOST	86bcd	89ab

Table 2.10 Continued

Fluridone	0.25	PRE	87bcd	89ab
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST		
Isoxaflutole	0.11	PRE	90abc	85ab
Dicamba+glyphosate+dimethenamid-P	0.56+1.26+0.67	EPOST		
Isoxaflutole+fluometuron	0.05+0.25	PRE	80d	86ab
Dicamba+glyphosate+isoxaflutole	0.56+1.26+0.05	EPOST		
Isoxaflutole+fluometuron	0.11+1.12	PRE	89a-d	90ab
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST		
Isoxaflutole+dicamba	0.11+0.56	PRE	88a-d	81b
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST		
Fluometuron+pendimethalin	1.12+1.07	PRE	84bcd	71c
Glufosinate+glyphosate+isoxaflutole	0.88+1.26+0.11	EPOST		
Fluometuron	1.12	PRE	81cd	69c
Glufosinate+glyphosate+dimethenamid-P	0.88+1.26+0.67	EPOST		

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[a] Abbreviations: PRE, preemergence; EPOST, early-postemergence.

[b] Means within a column followed by the same letter are not significantly different according to Fisher’s Protected LSD at $P < 0.05$.

Table 2.11. Lint yield in 2021 and 2022 in Axant™ Flex cotton systems.

Treatments	Rate	Application timing[a]	Cotton lint yield[b] 2021	Cotton lint yield[b] 2022
	kg ai or ae ha^{-1}		--------------------kg ha^{-1}--------------------	
Nontreated control	--	--	0c	0d
Isoxaflutole+pendimethalin Dicamba+glyphosate+dimethenamid-P	0.11+1.07 0.56+1.26+0.67	PRE EPOST	1609ab	2031ab
Isoxaflutole+fluridone Dicamba+glyphosate+dimethenamid-P	0.11+0.25 0.56+1.26+0.67	PRE EPOST	1507ab	2200a
Isoxaflutole+fluometuron Dicamba+glyphosate+dimethenamid-P	0.11+1.12 0.56+1.26+0.67	PRE EPOST	1471b	1958abc
Isoxaflutole+acetochlor Dicamba+glyphosate+dimethenamid-P	0.11+1.26 0.56+1.26+0.67	PRE EPOST	1577ab	1995abc
Pendimethalin+fluometuron Dicamba+glyphosate+isoxaflutole	1.07+1.12 0.56+1.26+0.11	PRE EPOST	1558ab	1929abc
Acetochlor+fluometuron Dicamba+glyphosate+acetochlor	1.26+1.12 0.56+1.26+1.26	PRE EPOST	1490b	1746bc
Fluometuron Dicamba+glyphosate+dimethenamid-P	1.12 0.56+1.26+0.67	PRE EPOST	1543ab	2043ab

Table 2.11 Continued

Fluridone Dicamba+glyphosate+dimethenamid-P	0.25 0.56+1.26+0.67	PRE EPOST	1511ab	1944abc
Isoxaflutole Dicamba+glyphosate+dimethenamid-P	0.11 0.56+1.26+0.67	PRE EPOST	1650a	1682bc
Isoxaflutole+fluometuron Dicamba+glyphosate+isoxaflutole	0.05+0.25 0.56+1.26+0.05	PRE EPOST	1567ab	2002ab
Isoxaflutole+fluometuron Glufosinate+glyphosate+dimethenamid-P	0.11+1.12 0.88+1.26+0.67	PRE EPOST	1489b	2272a
Isoxaflutole+dicamba Glufosinate+glyphosate+dimethenamid-P	0.11+0.56 0.88+1.26+0.67	PRE EPOST	1621ab	1916abc
Fluometuron+pendimethalin Glufosinate+glyphosate+isoxaflutole	1.12+1.07 0.88+1.26+0.11	PRE EPOST	1542ab	1642bc
Fluometuron Glufosinate+glyphosate+dimethenamid-P	1.12 0.88+1.26+0.67	PRE EPOST	1512ab	1594c

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[a] Abbreviations: PRE, preemergence; EPOST, early-postemergence.

[b] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at $P < 0.05$.

CHAPTER III

PREEMERGENCE PALMER AMARANTH CONTROL WITH ISOXAFLUTOLE TANK-MIX COMBINATIONS

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ABSTRACT

Palmer amaranth (*Amaranthus palmeri* S. Wats.) is the most common and troublesome weed in cotton production. Palmer amaranth resistance to glyphosate adds to the complexity of management and reports of resistance to other modes of action used in cotton creates the need for new management strategies to control this troublesome pest. Axant™ Flex cotton from BASF will allow isoxaflutole, a HRAC group 27 herbicide, to be used preemergence or early-postemergence to aid in weed management. The objective of our study was to evaluate Palmer amaranth control and duration of control following isoxaflutole in tank-mix combinations. Isoxaflutole at 0.07 and 0.11 kg ai ha^{-1} was included in tank-mix combinations with commercially available cotton soil-active herbicides. Isoxaflutole at 0.07 kg ai ha^{-1} plus *S*-metolachlor was the only treatment that provided >90% Palmer amaranth control 42 days after application in both years. In 2022, the addition of isoxaflutole with dicamba and pendimethalin improved Palmer amaranth control 42 days after application compared to these herbicides applied alone. Isoxaflutole lengthened the duration of control for all tank-mix partners except dimethenamid-P in 2021. The use of isoxaflutole will provide another tool to help manage herbicide-resistant and other troublesome weeds in cotton.

Nomenclature: Palmer amaranth, *Amaranthus palmeri* S. Wats.

Keywords: isoxaflutole, weed control, duration of control, tank-mix

INTRODUCTION

Palmer amaranth (*Amaranthus palmeri* S. Wats.) is one of four dioecious *Amaranthus* species native to the southwestern United States and Mexico, and has spread further from its origin than the other *Amaranthus* species (Steckel 2007). Palmer amaranth has transitioned from one of the most common weeds in cotton (*Gossypium hirsutum* L.) to one of the most troublesome. Glyphosate-resistant Palmer amaranth was first discovered in United States cotton production in Georgia and North Carolina in 2005 (Heap 2023). Recently, resistance to other cotton herbicides has been discovered. Dicamba-resistant Palmer amaranth was identified in Tennessee cotton and glufosinate resistance was identified in Arkansas cotton in 2020. Herbicide-resistance increases the need for new weed management options in cotton and other agronomic crops. Before the adoption of glyphosate-resistant crops, weed management in cotton was heavily reliant on the use of soil residual herbicides (Young 2006). The use of multiple modes of action and soil residual herbicides are important best management practices to combat herbicide resistance (Cahoon and York 2023).

Isoxaflutole, a HRAC Group 27 herbicide, is a hydroxyphenyl pyruvate dioxygenase (HPPD) inhibitor (HRAC 2023). This herbicide works by preventing the production of carotenoids, which protect the chloroplast from photodecomposition. Isoxaflutole is rapidly converted to diketonitrile, its active derivative, after plant uptake. The conversion to diketonitrile also can take place in the soil before plant uptake. Diketonitrile is mobile in both the xylem and phloem and it is highly systemic (Pallett et al. 2001). Isoxaflutole was initially registered for use in field corn (*Zea mays* L.) in 1998 (EPA 1998) and has activity on a broad spectrum broadleaf and grassy weeds.

Isoxaflutole can help control weeds that have resistance to other modes of action (Minnesota Department of Agriculture 2015). Axant™ Flex cotton from BASF provides the ability to utilize isoxaflutole, an option that has not been previously available for use in cotton.

Previous studies have evaluated isoxaflutole tank-mix partners using a single rate of isoxaflutole with differing rates of the tank-mix partners. Isoxaflutole alone and isoxaflutole plus tank-mix partners were reported to provide ≥93% Palmer amaranth control on the Texas High Plains (Foster et al. 2021). The objective of our study was to evaluate Palmer amaranth control and the duration of control with isoxaflutole tank-mix combinations.

MATERIALS AND METHODS

Field studies were conducted in 2021 and 2022 at the Texas A&M AgriLife Research Station in Halfway, Texas (34.18604 N, -101.94592 W). This location is equipped with overhead sprinkler irrigation. The soil type is a Pullman clay loam with 8.1 pH, <1% organic matter, and 26.4 CEC. Non-crop trials were established on May 17, 2021, and May 16, 2022. Plot size, 4.1 by 9.1 meters, were arranged in a randomized complete block design (RCBD) with four replications. The 2021 study was analyzed as a three-replication trial due to the absence of uniform weed pressure in the fourth replication. Total in-season irrigation was 32 and 116 mm in 2021 and 2022, respectively. Total in-season rainfall was 197 and 50 mm in 2021 and 2022, respectively. Treatments (Table 3.1) were applied on the day adjacent cotton trials were planted. Paraquat at 0.56 kg ai ha^{-1} plus nonionic surfactant at 0.25% v/v was used immediately after trial establishment to provide an initial weed-free setting. All applications were made with a CO_2-pressurized backpack sprayer at 140 L ha^{-1} using TT 11002 nozzles (TeeJet® Technologies, Glendale Heights, IL).

Palmer amaranth control was evaluated 14, 28, 42 and 56 days after the PRE application. Control was evaluated on a 0-100% scale with 0% being no weeds controlled and 100% being all weeds controlled when compared to the nontreated control (Frans et al. 1986). Weed density was recorded from two locations in the center of each plot using 0.25 m^2 quadrats. Analysis of variance was conducted using the GLIMMIX procedure in SAS (version 9.4; SAS Institute Inc., Cary, NC). Means separation was analyzed using Fisher's least significant difference (LSD) at $\alpha=0.05$ for all analyses. Scatter plots and linear regressions were analyzed using Microsoft Excel 2018.

RESULTS AND DISCUSSION

Visual Palmer amaranth Control

Conditions during the 2021 and 2022 growing season were different (Table 3.2). There was less rainfall in 2022 around the time of trial establishment and throughout the growing season. Palmer amaranth control ranged from 30 to 95% for all treatments 14 days after application in 2021 (Table 3.3). Palmer amaranth control ranged from 30 to 95% when the preemergence herbicides were sprayed alone. Fomesafen and *S*-metolachlor were the only treatments that provided ≥90% Palmer amaranth control 14 days after application when applied without a tank-mix partner in 2021. Isoxaflutole at 0.07 kg ai ha^{-1} applied with a tank-mix partner controlled Palmer amaranth 53 to 93% 14 days after application in 2021. The only treatments that provided >90% Palmer amaranth control were isoxaflutole plus fomesafen, fluridone, or *S*-metolachlor. Palmer amaranth control was ≥70% 14 days after application when isoxaflutole at 0.11 kg ai ha^{-1} was included with a tank-mix partner. Palmer amaranth control was ≥90% with isoxaflutole plus fluridone, diuron, fluometuron, dimethenamid-P, or dicamba.

In 2022, Palmer amaranth control 14 days after application ranged from 46 to 100% (Table 3.3). Preemergence herbicides applied alone controlled Palmer amaranth 46 to 99%. Palmer amaranth control was >90% with isoxaflutole at 0.11 kg ai ha^{-1}, fomesafen, fluridone, fluometuron, *S*-metolachlor, and dimethenamid-P. Isoxaflutole at 0.07 kg ai ha^{-1} included with a tank-mix partner controlled Palmer amaranth ≥88%. Diuron was the only treatment that did not control Palmer amaranth >90% when mixed with isoxaflutole at 0.07 kg ai ha^{-1}. Palmer amaranth control was ≥95% for all treatments when isoxaflutole at 0.11 kg ai ha^{-1} was included in the tank-mix.

Palmer amaranth control 28 days after application ranged from 30 to 94% in 2021 and 6 to 98% in 2022 (Table 3.4). Preemergence herbicides applied alone controlled Palmer amaranth 30 to 92% in 2021. Isoxaflutole at 0.07 kg ai ha^{-1} in tank-mix combinations provided 45 to 94% Palmer amaranth control 28 days after application. Isoxaflutole tank-mixed with fomesafen, fluridone, or isoxaflutole were the only treatments that provided >90% Palmer amaranth control at this timing. Isoxaflutole at 0.11 kg ai ha^{-1} included in tank-mix controlled Palmer amaranth 62 to 94% 28 days after treatment in 2021. Isoxaflutole plus fomesafen or acetochlor were the only treatments that provided >90% control. In 2022, treatments without isoxaflutole that provided ≥90% Palmer amaranth control 28 days after application included fluometuron, *S*-metolachlor, and dimethenamid-P (Table 3.4). The least Palmer amaranth control was observed following pendimethalin (6%) 28 days after application. Isoxaflutole at 0.07 and 0.11 kg ai ha^{-1} tank-mixed with pendimethalin controlled Palmer amaranth 83% and 93%, respectively. Isoxaflutole at 0.07 and 0.11 kg ai ha^{-1} as a tank-mix partner controlled Palmer amaranth ≥70% and ≥85%, respectively.

At 42 days after application in 2021, many of the treatments were starting to breakdown (Table 3.5). The only treatments that provided ≥90% Palmer amaranth control at this timing were isoxaflutole at 0.07 kg ai ha^{-1} plus *S*-metolachlor and isoxaflutole at 0.11 kg ai ha^{-1} plus acetochlor. The only herbicides that provided ≥71% Palmer amaranth control when applied alone were fomesafen, *S*-metolachlor, and dimethenamid-P. In 2022, Palmer amaranth control improved when isoxaflutole was added to pendimethalin and dicamba (Table 3.5). At this timing, the only treatments that controlled Palmer amaranth ≥90% were isoxaflutole at 0.07 kg ai ha^{-1} plus fluometuron, *S*-metolachlor, or dimethenamid-P, and isoxaflutole at 0.11 kg ai ha^{-1} plus fomesafen, fluridone, prometryn, *S*-metolachlor, or dimethenamid-P. Palmer amaranth control was ≥80% following fluometuron, *S*-metolachlor, and dimethenamid-P applied alone.

In 2021, no differences were observed among treatments 56 days after application and all treatments had deteriorated to where Palmer amaranth control was <70% (Table 3.6). In 2022, none of the treatments controlled Palmer amaranth ≥90% at 56 days after planting. Palmer amaranth control was >80% following isoxaflutole at 0.07 kg ai ha^{-1} plus dimethenamid-P, and isoxaflutole at 0.11 kg ai ha^{-1} plus fomesafen, prometryn, fluometuron, *S*-metolachlor, or dimethenamid-P (Table 3.6).

Palmer amaranth Density

Palmer amaranth density differences were not determined among treatments 14 days after application in 2021 (Table 3.3). Densities ranged from 33,000 to 1,067,000 plants ha^{-1} 14 days after application in 2021. In 2022, densities ranged from 0 to

1,035,000 plants ha^{-1} 14 days after application (Table 3.3). All isoxaflutole tank-mix combinations caused lower Palmer amaranth densities than pendimethalin, diuron, and dicamba applied alone 14 days after application in 2022. Palmer amaranth densities following isoxaflutole tank-mix combinations were ≤45,000 weeds ha^{-1} 14 days after application in 2022.

No differences in Palmer amaranth density were detected among treatments 28 days after application in 2021 (Table 3.4), where Palmer amaranth densities ranged from 0 to 606,000 plants ha^{-1}. All isoxaflutole-containing treatments caused lower Palmer amaranth densities than pendimethalin, diuron, and dicamba applied alone when evaluated 28 days after application in 2022 (Table 3.4). Pendimethalin, diuron, and dicamba treatments allowed ≥575,000 Palmer amaranth plants ha^{-1} 28 days after application in 2022. Palmer amaranth densities were not different among isoxaflutole-containing treatments and among fomesafen, fluridone, prometryn, fluometuron, acetochlor, *S*-metolcachlor, or dimethenamid-P applied alone.

Palmer amaranth density differences were not detected among treatments 42 days after application in 2021 (Table 3.5), and densities ranged from 13,000 to 253,000 plants ha^{-1}. In 2022, pendimethalin, diuron, and dicamba had greater Palmer amaranth densities than all other treatments, but were not different from the nontreated control 42 days after application (Table 3.5). Palmer amaranth densities were ≥580,000 plants ha^{-1} following pendimethalin, diuron, and dicamba, while ≤235,000 plants ha^{-1} were observed from all other treatments were 42 days after application in 2022.

In 2021, no differences in Palmer amaranth density were detected 56 days after application (Table 3.6), where densities ranged from 27,000 to 227,000 plants ha^{-1}. In

2022, all treatments reduced Palmer amaranth densities when compared to the nontreated control (Table 3.6). Fomesafen applied alone had fewer Palmer amaranth escapes than diuron applied alone 56 days after application in 2022. Pendimethalin, diuron, and dicamba had greater Palmer amaranth densities than many of the isoxaflutole tank-mix combinations, but these treatments were not different from all isoxaflutole-containing treatments as reported at earlier observation timings.

Extension of Palmer amaranth Control as a Tank-Mix Partner

The addition of isoxaflutole extended the duration Palmer amaranth control with many of the herbicides evaluated. Linear regressions were used to create a predictive model allowing for comparisons among treatments with and without the addition of isoxaflutole. In 2021, 90% Palmer amaranth control was maintained for 20 more days when isoxaflutole at 0.11 kg ai $^{-1}$ was added to acetochlor compared to acetochlor applied alone (Figure 3.1). Palmer amaranth control at 80% was maintained for 33 more days when isoxaflutole at 0.11 kg ai ha^{-1} was added to acetochlor. Similar results were observed in 2022 as 90% Palmer amaranth control was maintained for 15 more days and 80% control was maintained for 25 more days when isoxaflutole at 0.11 kg ai ha^{-1} was added to acetochlor compared to acetochlor applied alone (Figure 3.11).

Isoxaflutole added to dicamba extended Palmer amaranth control in both years. In 2021, dicamba alone never achieved 90% Palmer amaranth control (Figure 3.2). Isoxaflutole at 0.11 kg ai ha^{-1} plus dicamba controlled Palmer amaranth at 90% for 15 days, which is 12 more days than isoxaflutole at 0.07 kg ai ha^{-1} plus dicamba. Palmer amaranth control at 80% was maintained for 20 more days and at 70% was maintained for 21 more days when isoxaflutole at 0.11 kg ai ha^{-1} was added to dicamba when compared to dicamba alone. In 2022, Palmer amaranth was controlled at 90%, 80%, and 70% for 17, 20, and 24 more days, respectively, when isoxaflutole at 0.11 kg ai ha^{-1} was added to dicamba compared to dicamba applied alone (Figure 3.12). Isoxaflutole at 0.07 kg ai ha^{-1} plus dicamba extended the control of Palmer amaranth at 90%, 80%, and 70% for 13, 16, and 19 more days when compared to dicamba applied alone.

When isoxaflutole was added to dimethenamid-P, no improvement in Palmer amaranth control was observed compared to dimethenamid-P applied alone in 2021 (Figure 3.3). In 2022, the addition of isoxaflutole to dimethenamid-P extended the duration of 90% and 80% Palmer amaranth control 14 to 56 days after application (Figure 3.13). These large increases in extended Palmer amaranth control may be due to the limited rainfall to promote weed flushes in 2022.

Palmer amaranth control with diuron was maintained at 90% and 80% for 18 and 24 more days when isoxaflutole at 0.11 kg ai ha^{-1} was added in 2021 (Figure 3.4). In 2022, diuron alone never reached 90% Palmer amaranth control (Figure 3.14). Palmer amaranth control was controlled 90% for 20 days with isoxaflutole at 0.11 kg ai ha^{-1} plus diuron, which was 9 more days when compared to isoxaflutole at 0.07 kg ai ha^{-1} plus diuron. Palmer amaranth was controlled at 80% and 70% for 33 and 41 more days, respectively, when isoxaflutole at 0.11 kg ai ha^{-1} was added to diuron compared to diuron applied alone.

Palmer amaranth control with fluometuron was extended 10 days when isoxaflutole at 0.11 kg ai ha^{-1} was added to fluometuron compared to fluometuron applied alone. Palmer amaranth was controlled at 80% for 30 more days and at 70% for 36 more days with isoxaflutole at 0.11 kg ai ha^{-1} plus fluometuron compared to fluometuron alone.

In 2022, Palmer amaranth was controlled 90% for 9 to 22 more days, at 80% for 17 to 43 more days, and at 70% for 26 to 65 more days with isoxaflutole at 0.11 kg ai ha^{-1} or 0.07 kg ai ha^{-1} plus fluometuron compared to fluometuron alone (Figure 3.15).

In 2021, fluridone alone never achieved 80% Palmer amaranth control (Figure 3.6). There was little extension of Palmer amaranth control observed between the different rates of isoxaflutole when added to fluridone. In 2022, Palmer amaranth was controlled 90% for 11 more days, at 80% for 16 more days, and at 70% for 22 more days with isoxaflutole at 0.11 kg ai ha^{-1} plus fluridone compared to fluridone alone (Figure 3.16).

In 2021, Palmer amaranth control was not extended more than 9 days when isoxaflutole was added to fomesafen (Figure 3.7). Palmer amaranth was controlled at 70% for 9 more days with isoxaflutole at 0.11 kg ai ha^{-1} plus fomesafen compared to fomesafen alone. In 2022, Palmer amaranth was controlled 90% for 11 more days when isoxaflutole at 0.07 kg ai ha^{-1} was added and for 32 more days when isoxaflutole at 0.11 kg ai ha^{-1} was added to fomesafen (Figure 3.17). Large extensions in control were predicted at the 70 and 80% Palmer amaranth control thresholds. These large extensions could be due to the high level of control observed with isoxaflutole at 0.11 kg ai ha^{-1} plus fomesafen and limited rainfall during the growing season in 2022.

Pendimethalin alone did not achieve 90% Palmer amaranth control in either year. Isoxaflutole at 0.11 kg ai^{-1} plus pendimethalin controlled Palmer amaranth 90% for 10 and 24 days in 2021 and 2022, respectively. In 2021, Palmer amaranth was controlled 70% for 30 more days with isoxaflutole at 0.11 kg ai ha^{-1} plus pendimethalin compared to pendimethalin alone (Figure 3.8). In 2022, Palmer amaranth was controlled 80% for 24 more days and at 70% for 29 more days with isoxaflutole at 0.07 kg ai ha^{-1} plus pendimethalin compared to pendimethalin alone (Figure 3.18). Palmer amaranth control was maintained at 80% for 36 more days and at 70% for 45 more days with isoxaflutole at 0.11 kg ai ha^{-1} plus pendimethalin compared to pendimethalin alone.

In 2021, Palmer amaranth control was extended for up to 7 days with isoxaflutole at 0.11 kg ai ha^{-1} plus prometryn compared to prometryn alone (Figure 3.9). In 2022, Palmer amaranth control was maintained at 90% for 29 more days with isoxaflutole at 0.11 kg ai ha^{-1} plus prometryn compared to prometryn alone (Figure 3.19). Large extensions were observed at the 70 and 80% thresholds, which may be due to limited rainfall in 2022.

In 2021, isoxaflutole at 0.07 kg ai ha^{-1} plus *S*-metolachlor maintained 90% Palmer amaranth control 15 more days and 80% control was extended for 27 more days compared to *S*-metolachlor alone (Figure 3.10). There was no benefit when isoxaflutole at 0.11 kg ai ha^{-1} was added to *S*-metolachlor. In 2022, isoxaflutole at 0.11 kg ai ha^{-1} plus *S*-metolachlor maintained 90 and 80% Palmer amaranth control 16 and 30 more days than *S*-metolachlor applied alone (Figure 3.20). The addition of isoxaflutole at 0.07 kg ai ha^{-1} plus *S*-metolachlor was similar to the addition of isoxaflutole at 0.11 kg ai ha^{-1}.

SUMMARY

The addition of isoxaflutole to a cotton residual herbicide program has the ability to enhance and extend the duration of Palmer amaranth control. Isoxaflutole tank-mixed with diuron, fluridone, or *S*-metolachlor were effective options to control broadleaf weeds (Foster et al. 2021). Isoxaflutole plus fomesafen, fluridone, fluometuron, *S*-metolachlor, or dimethenamid-P provided greater levels of Palmer amaranth control regardless of the rate of isoxaflutole used and could be effective options in an Axant™ Flex cotton system. In many cases, Palmer amaranth control was lengthened when isoxaflutole was included with tank-mix partner. The addition of isoxaflutole at 0.11 kg ai ha^{-1} to acetochlor extended the duration of 90% Palmer amaranth control at least 15 days in both years. Isoxaflutole at 0.11 kg ai ha^{-1} plus diuron extended the duration of 90% Palmer amaranth control at least 9 days in both years. The addition of isoxaflutole to dicamba or pendimethalin improved the duration of control of Palmer amaranth in both years compared to the herbicide alone. Isoxaflutole at 0.11 kg ai ha^{-1} plus fluometuron extended the duration of control at least 10 days in both years compared to fluometuron alone. The opportunity to use isoxaflutole in cotton will provide an effective preemergence option to aid in the control of troublesome weeds.

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Table 3.1. Treatments, rates, and timing for isoxaflutole tank-mix partner trials in 2021 and 2022

Preemergence treatment	Rate
	kg ai or ae ha^{-1}
Nontreated control	--
Isoxaflutole	0.07
Isoxaflutole	0.11
Pendimethalin	1.07
Fomesafen	0.28
Fluridone	0.25
Prometryn	1.12
Diuron	0.84
Fluometuron	1.12
Acetochlor	1.26
S-metolachlor	1.40
Dimethenamid-P	0.67
Dicamba	0.56
Isoxaflutole+pendimethalin	0.07+1.07
Isoxaflutole+fomesafen	0.07+0.28
Isoxaflutole+fluridone	0.07+0.25
Isoxaflutole+prometryn	0.07+1.12
Isoxaflutole+diuron	0.07+0.84
Isoxaflutole+fluometuron	0.07+1.12
Isoxaflutole+acetochlor	0.07+1.26
Isoxaflutole+*S*-metolachlor	0.07+1.40
Isoxaflutole+dimethenamid-P	0.07+0.67
Isoxaflutole+dicamba	0.07+0.56
Isoxaflutole+pendimethalin	0.11+1.07
Isoxaflutole+fomesafen	0.11+0.28
Isoxaflutole+fluridone	0.11+0.25
Isoxaflutole+prometryn	0.11+1.12
Isoxaflutole+diuron	0.11+0.84
Isoxaflutole+fluometuron	0.11+1.12
Isoxaflutole+acetochlor	0.11+1.26
Isoxaflutole+*S*-metolachlor	0.11+1.40
Isoxaflutole+dimethenamid-P	0.11+0.67
Isoxaflutole+dicamba	0.11+0.56

Table 3.2. Rainfall and irrigation amounts by month in 2021 and 2022.

	2021		2022	
Month[a]	Rainfall	Irrigation	Rainfall	Irrigation
	----------mm----------			
May	100	12	41	56
June	74	20	1	30
July	23	0	8	30
Total	197	32	50	116

[a] Totals for May begin when trial was established. Totals for July end when trial was completed.

Table 3.3. Visual Palmer amaranth control and density 14 days after preemergence application.

		Palmer amaranth[a]			
		2021		2022	
Treatment	Rate	Control	Density	Control	Density
	kg ai or ae ha^{-1}	-----%-----	1,000 plants ha^{-1}	-----%-----	1,000 plants ha^{-1}
Nontreated control	--	0g	253	0g	1,035a
Isoxaflutole	0.07	58a-f	147	81bc	260cd
Isoxaflutole	0.11	52c-f	273	91abc	50d
Pendimethalin	1.07	30fg	193	61ef	385bc
Fomesafen	0.28	95a	40	98a	5d
Fluridone	0.25	32efg	227	94abc	80d
Prometryn	1.12	75a-d	187	83abc	80cd
Diuron	0.84	68a-f	273	46f	660b
Fluometuron	1.12	77a-d	187	99a	5d
Acetochlor	1.26	83a-d	127	80cd	105cd
S-metolachlor	1.40	90abc	45	96ab	55d
Dimethenamid-P	0.67	83a-d	100	97a	5d
Dicamba	0.56	43def	1,067	65de	585b
Isoxaflutole+pendimethalin	0.07+1.07	82a-d	133	90abc	40d
Isoxaflutole+fomesafen	0.07+0.28	93ab	60	98a	0d
Isoxaflutole+fluridone	0.07+0.25	92abc	33	93abc	20d
Isoxaflutole+prometryn	0.07+1.12	63a-f	320	97a	25d
Isoxaflutole+diuron	0.07+0.84	72a-e	147	88abc	40d
Isoxaflutole+fluometuron	0.07+1.12	53b-f	187	99a	0d
Isoxaflutole+acetochlor	0.07+1.26	80a-d	200	93abc	45d
Isoxaflutole+*S*-metolachlor	0.07+1.40	93ab	40	97a	25d
Isoxaflutole+dimethenamid-P	0.07+0.67	85abc	40	100a	0d

Table 3.3 Continued

Isoxaflutole+dicamba	0.07+0.56	73a-d	180	90abc	45d
Isoxaflutole+pendimethalin	0.11+1.07	70a-f	307	97a	0d
Isoxaflutole+fomesafen	0.11+0.28	88abc	93	100a	0d
Isoxaflutole+fluridone	0.11+0.25	95a	73	100a	0d
Isoxaflutole+prometryn	0.11+1.12	80a-d	147	100a	5d
Isoxaflutole+diuron	0.11+0.84	93ab	27	95abc	35d
Isoxaflutole+fluometuron	0.11+1.12	90abc	127	100a	0d
Isoxaflutole+acetochlor	0.11+1.26	95a	53	95abc	10d
Isoxaflutole+*S*-metolachlor	0.11+1.40	80a-d	240	97a	10d
Isoxaflutole+dimethenamid-P	0.11+0.67	92abc	67	98a	15d
Isoxaflutole+dicamba	0.11+0.56	92abc	67	95abc	40d

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[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at $P < 0.05$.

Table 3.4. Visual Palmer amaranth control and density 28 days after preemergence application.

		Palmer amaranth[a]			
		2021		2022	
Treatment	Rate	Control	Density	Control	Density
	kg ai or ae ha^{-1}	-----%-----	1,000 plants ha^{-1}	-----%-----	1,000 plants ha^{-1}
Nontreated control	--	0h	453	0h	950ab
Isoxaflutole	0.07	56c-g	133	69f	205d
Isoxaflutole	0.11	56c-g	213	74def	255d
Pendimethalin	1.07	38efg	260	6h	1,000a
Fomesafen	0.28	87abc	73	88a-d	90d
Fluridone	0.25	30gh	180	85a-e	100d
Prometryn	1.12	37fg	173	80b-f	160d
Diuron	0.84	59b-g	153	34g	685bc
Fluometuron	1.12	82abc	100	90abc	75d
Acetochlor	1.26	32fgh	140	68f	215d
S-metolachlor	1.40	79a-d	120	90abc	120d
Dimethenamid-P	0.67	92ab	73	94ab	40d
Dicamba	0.56	47d-g	606	34g	575c
Isoxaflutole+pendimethalin	0.07+1.07	78a-e	87	83a-f	150d
Isoxaflutole+fomesafen	0.07+0.28	94ab	0	95ab	20d
Isoxaflutole+fluridone	0.07+0.25	91abc	20	85a-e	115d
Isoxaflutole+prometryn	0.07+1.12	63a-g	147	93ab	35d
Isoxaflutole+diuron	0.07+0.84	66a-f	233	70ef	170d
Isoxaflutole+fluometuron	0.07+1.12	60b-g	113	93ab	20d
Isoxaflutole+acetochlor	0.07+1.26	65a-g	233	85a-e	65d
Isoxaflutole+*S*-metolachlor	0.07+1.40	97a	20	95ab	25d
Isoxaflutole+dimethenamid-P	0.07+0.67	88abc	33	96a	30d

Table 3.4 Continued

Isoxaflutole+dicamba	0.07+0.56	45d-g	120	95ab	160d
Isoxaflutole+pendimethalin	0.11+1.07	62b-g	153	93ab	45d
Isoxaflutole+fomesafen	0.11+0.28	93ab	40	98a	20d
Isoxaflutole+fluridone	0.11+0.25	87abc	67	96a	20d
Isoxaflutole+prometryn	0.11+1.12	67a-f	67	95ab	25d
Isoxaflutole+diuron	0.11+0.84	89abc	27	85a-e	105d
Isoxaflutole+fluometuron	0.11+1.12	88abc	40	96a	25d
Isoxaflutole+acetochlor	0.11+1.26	94ab	13	86a-d	95d
Isoxaflutole+*S*-metolachlor	0.11+1.40	85abc	47	95ab	15d
Isoxaflutole+dimethenamid-P	0.11+0.67	87abc	40	96a	20d
Isoxaflutole+dicamba	0.11+0.56	87abc	13	86a-d	115d

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[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at $P < 0.05$.

Table 3.5. Visual Palmer amaranth control and density 42 days after preemergence application.

		Palmer amaranth[a]			
		2021		2022	
Treatment	Rate	Control	Density	Control	Density
	kg ai or ae ha^{-1}	-----%-----	1,000 plants ha^{-1}	-----%-----	1,000 plants ha^{-1}
Nontreated control	--	0i	240	0i	675a
Isoxaflutole	0.07	53a-h	200	66fg	195b
Isoxaflutole	0.11	42d-h	127	71d-g	230b
Pendimethalin	1.07	37e-i	187	6i	795a
Fomesafen	0.28	82a-d	40	76c-f	100b
Fluridone	0.25	35e-i	200	78b-f	95b
Prometryn	1.12	30f-i	193	68efg	170b
Diuron	0.84	46c-h	67	26h	750a
Fluometuron	1.12	67a-g	113	80a-f	90b
Acetochlor	1.26	43d-h	73	56g	165b
S-metolachlor	1.40	71a-f	140	84a-e	90b
Dimethenamid-P	0.67	78a-d	67	85a-d	95b
Dicamba	0.56	27ghi	253	28h	580a
Isoxaflutole+pendimethalin	0.07+1.07	52a-h	67	76c-f	160b
Isoxaflutole+fomesafen	0.07+0.28	82a-d	27	86a-d	55b
Isoxaflutole+fluridone	0.07+0.25	78a-d	33	81a-f	145b
Isoxaflutole+prometryn	0.07+1.12	58a-h	207	85a-d	95b
Isoxaflutole+diuron	0.07+0.84	50b-h	47	66fg	235b
Isoxaflutole+fluometuron	0.07+1.12	58a-h	93	92abc	45b
Isoxaflutole+acetochlor	0.07+1.26	55a-h	147	80a-f	100b
Isoxaflutole+*S*-metolachlor	0.07+1.40	93a	20	94ab	45b
Isoxaflutole+dimethenamid-P	0.07+0.67	70a-f	27	93ab	45b

Table 3.5 Continued

Isoxaflutole+dicamba	0.07+0.56	23i	93	71d-g	115b
Isoxaflutole+pendimethalin	0.11+1.07	82a-d	67	88a-d	90b
Isoxaflutole+fomesafen	0.11+0.28	67a-g	73	92abc	60b
Isoxaflutole+fluridone	0.11+0.25	72a-e	33	90abc	45b
Isoxaflutole+prometryn	0.11+1.12	53a-h	73	94ab	50b
Isoxaflutole+diuron	0.11+0.84	83ab	40	83a-f	115b
Isoxaflutole+fluometuron	0.11+1.12	86abc	20	83abc	40b
Isoxaflutole+acetochlor	0.11+1.26	90ab	13	86a-d	125b
Isoxaflutole+*S*-metolachlor	0.11+1.40	75a-e	127	93abc	45b
Isoxaflutole+dimethenamid-P	0.11+0.67	63a-h	93	95a	40b
Isoxaflutole+dicamba	0.11+0.56	68a-f	33	73d-g	155b

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[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at $P < 0.05$.

Table 3.6. Visual Palmer amaranth control and density 56 days after preemergence application.

		Palmer amaranth[a]			
		2021		2022	
Treatment	Rate	Control	Density	Control	Density
	kg ai or ae ha^{-1}	-----%-----	1,000 plants ha^{-1}	-----%-----	1,000 plants ha^{-1}
Nontreated control	--	0	146	0l	435a
Isoxaflutole	0.07	0	153	29ijk	105b-f
Isoxaflutole	0.11	0	227	46f-j	90b-f
Pendimethalin	1.07	17	147	0l	155bcd
Fomesafen	0.28	35	67	51e-i	50c-f
Fluridone	0.25	5	133	48f-i	55b-f
Prometryn	1.12	8	220	46f-j	65b-f
Diuron	0.84	25	100	9kl	155b
Fluometuron	1.12	47	107	56d-h	70b-f
Acetochlor	1.26	0	67	29ijk	130b-e
S-metolachlor	1.40	47	53	68a-f	45def
Dimethenamid-P	0.67	33	220	34b-f	65b-f
Dicamba	0.56	5	133	10kl	150bc
Isoxaflutole+pendimethalin	0.07+1.07	33	67	46f-j	55b-f
Isoxaflutole+fomesafen	0.07+0.28	52	46	75a-d	25f
Isoxaflutole+fluridone	0.07+0.25	40	40	59c-g	60b-f
Isoxaflutole+prometryn	0.07+1.12	33	80	63b-g	40ef
Isoxaflutole+diuron	0.07+0.84	28	107	24jk	70b-f
Isoxaflutole+fluometuron	0.07+1.12	33	107	71a-e	40ef
Isoxaflutole+acetochlor	0.07+1.26	12	127	51f-i	50c-f
Isoxaflutole+*S*-metolachlor	0.07+1.40	69	47	78a-d	30ef
Isoxaflutole+dimethenamid-P	0.07+0.67	17	107	88a	35ef

Table 3.6 Continued

Isoxaflutole+dicamba	0.07+0.56	20	73	34hij	70b-f
Isoxaflutole+pendimethalin	0.11+1.07	42	73	59c-g	50c-f
Isoxaflutole+fomesafen	0.11+0.28	47	107	88a	25f
Isoxaflutole+fluridone	0.11+0.25	30	80	64b-f	35ef
Isoxaflutole+prometryn	0.11+1.12	20	67	84ab	40ef
Isoxaflutole+diuron	0.11+0.84	57	27	60c-g	45def
Isoxaflutole+fluometuron	0.11+1.12	62	53	84ab	60b-f
Isoxaflutole+acetochlor	0.11+1.26	65	80	69a-f	60b-f
Isoxaflutole+*S*-metolachlor	0.11+1.40	47	67	82abc	45def
Isoxaflutole+dimethenamid-P	0.11+0.67	25	107	88a	25f
Isoxaflutole+dicamba	0.11+0.56	28	80	40h-j	50d-f

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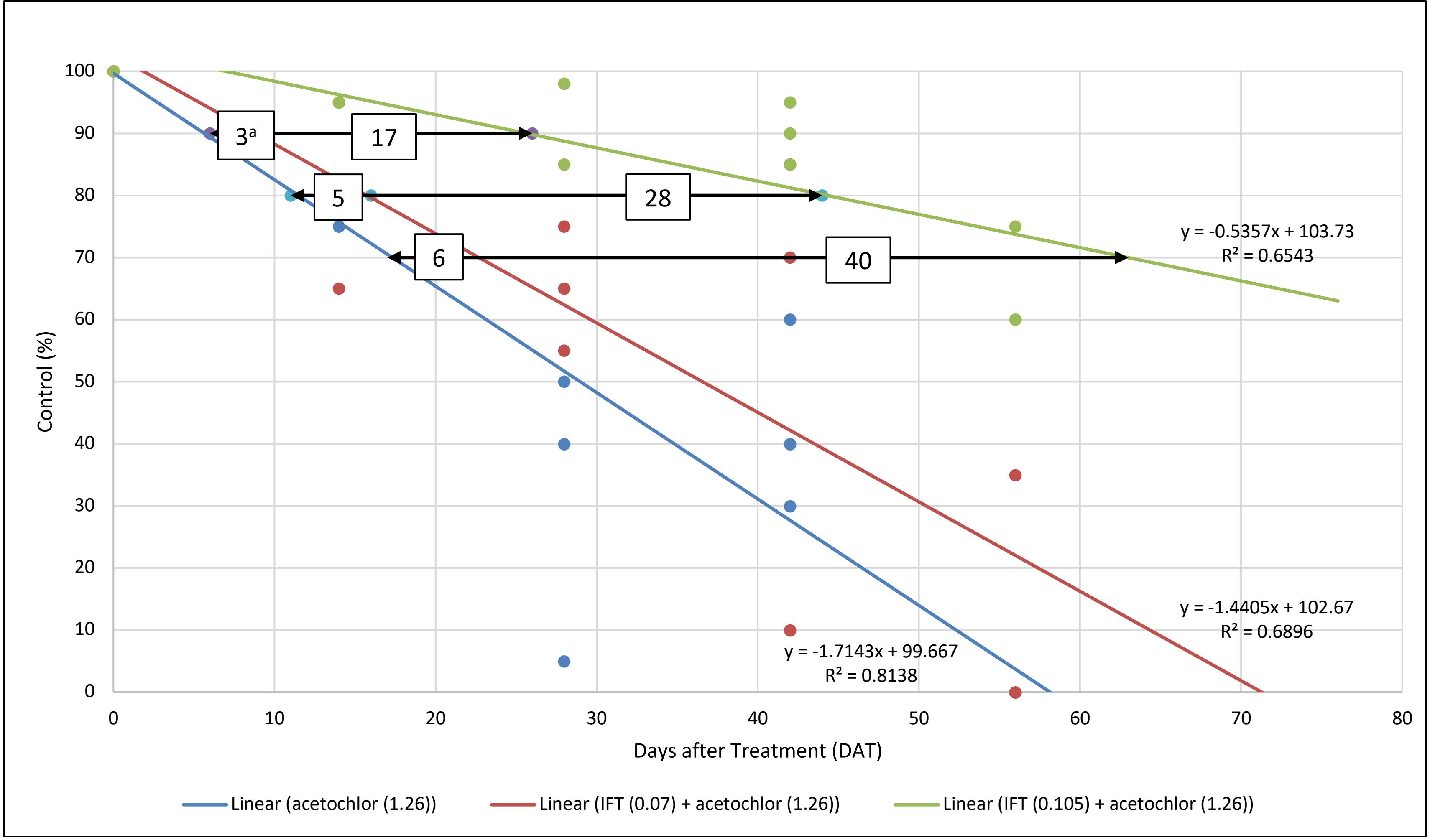
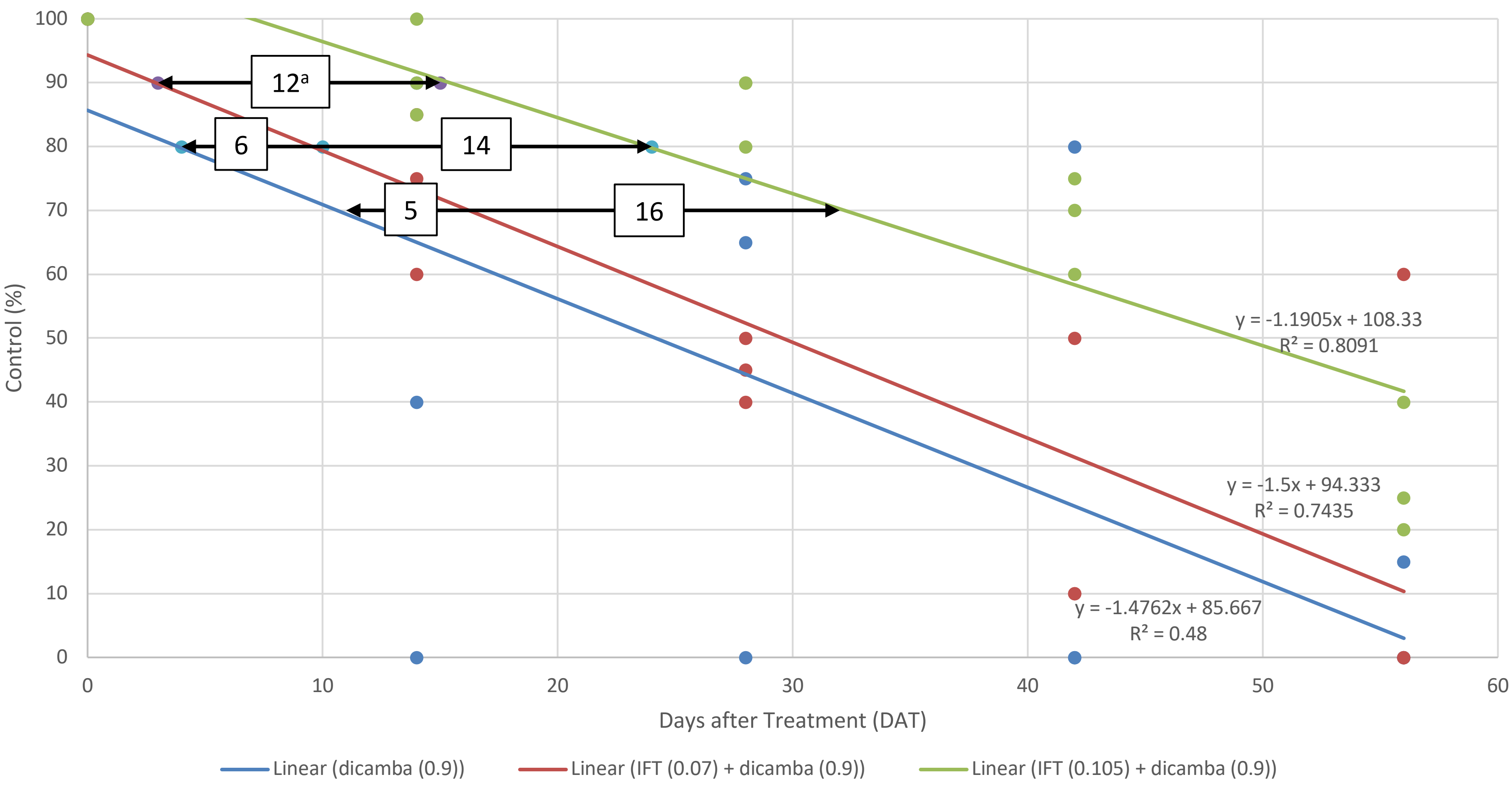
[a] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD at $P < 0.05$.

Figure 3.1. Predictive Palmer amaranth control for isoxaflutole plus acetochlor tank-mix combinations in 2021.



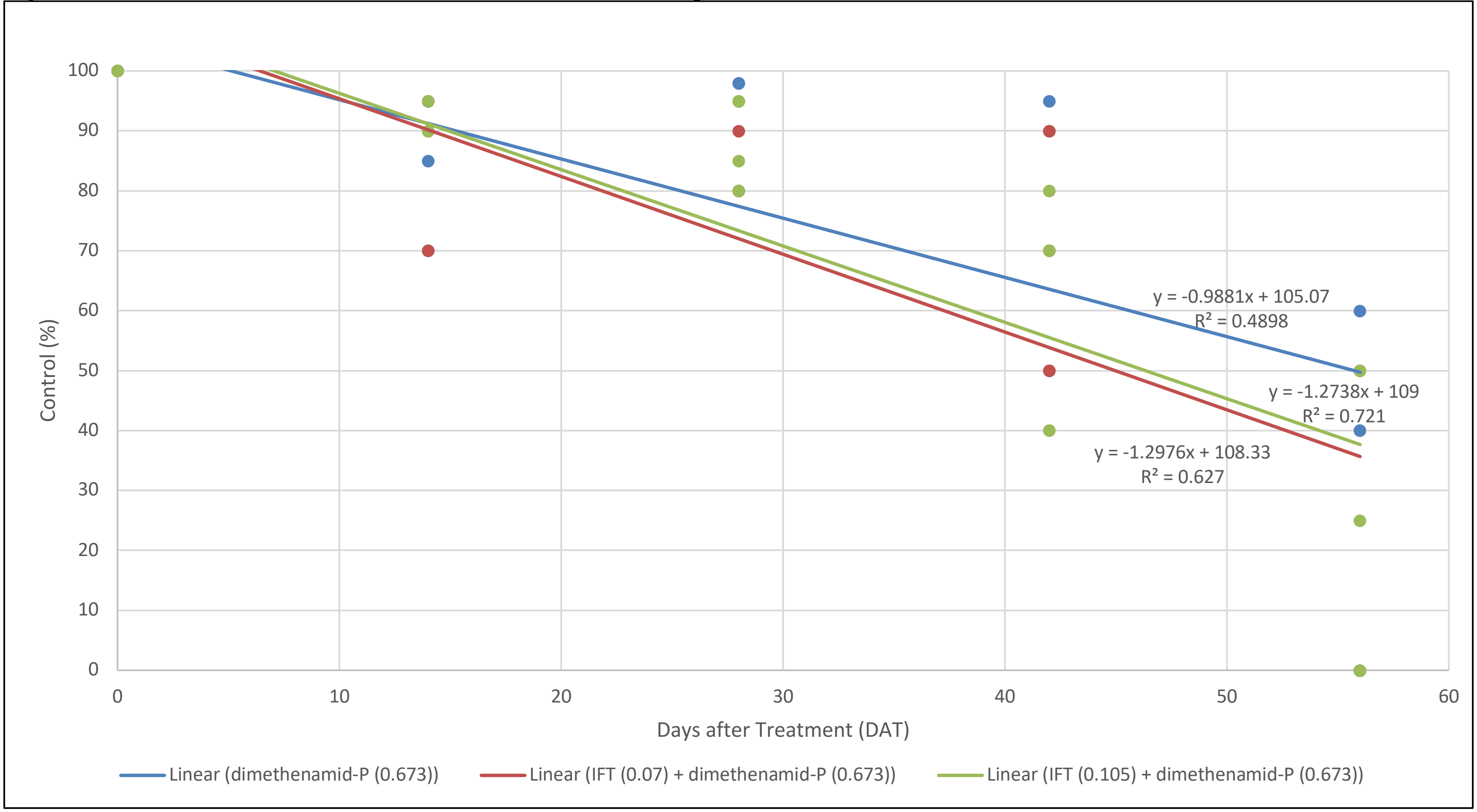
[a] Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.2. Predictive Palmer amaranth control for isoxaflutole plus dicamba tank-mix combinations in 2021.



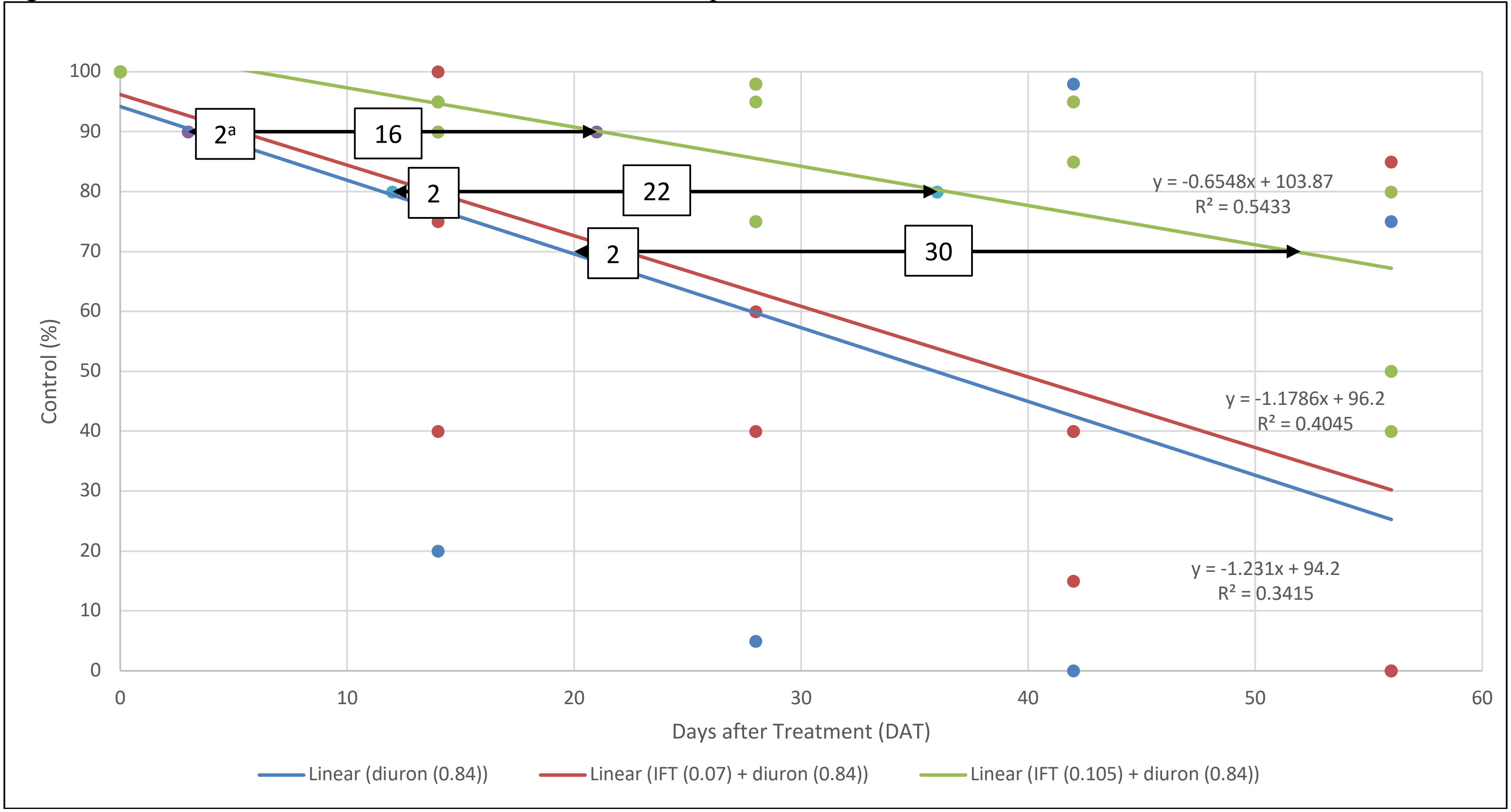
[a] Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.3. Predictive Palmer amaranth control for isoxaflutole plus dimethenamid-P tank-mix combinations in 2021.



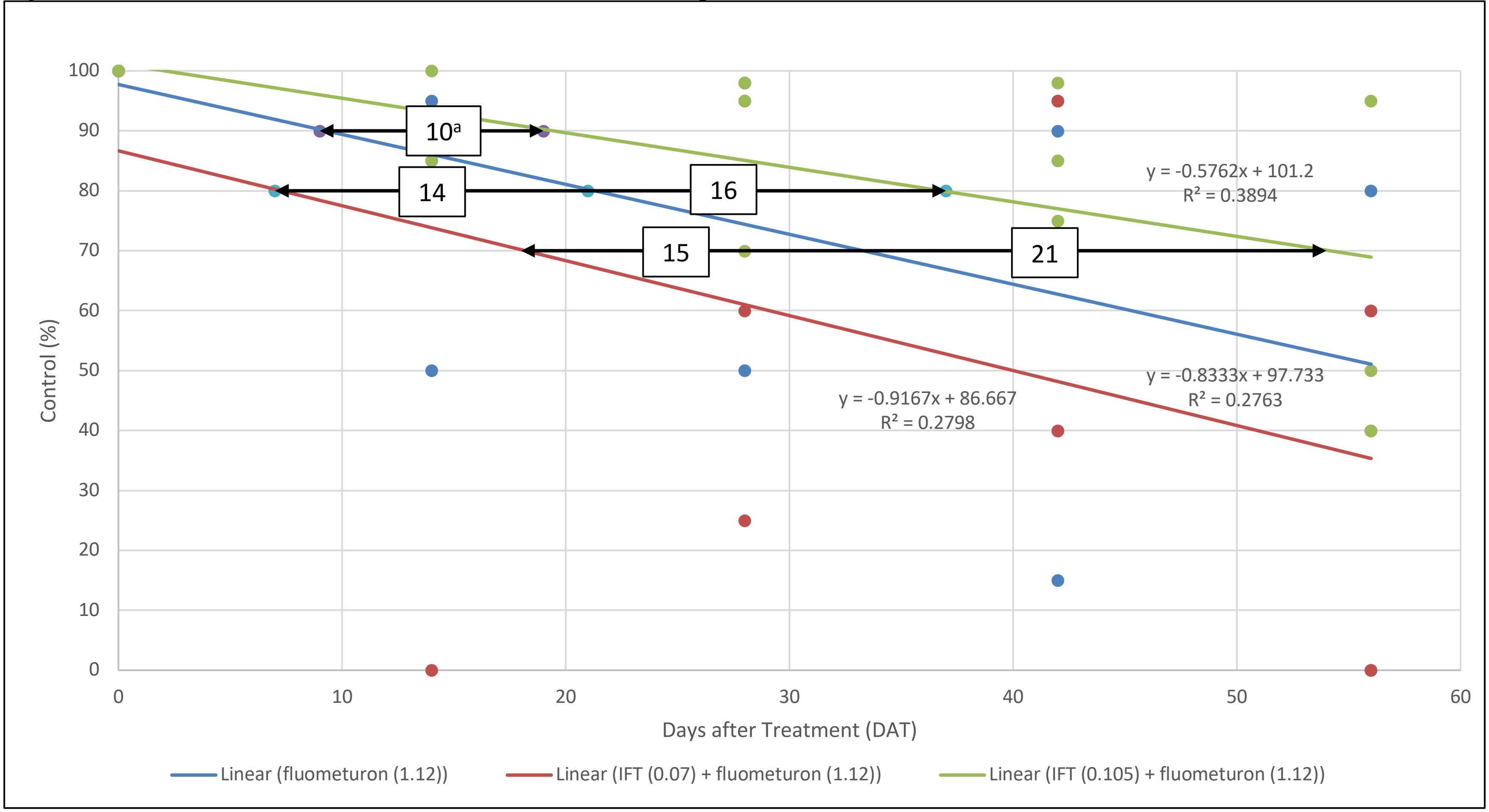
[a]Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.4. Predictive Palmer amaranth control for isoxaflutole plus diuron tank-mix combinations in 2021.



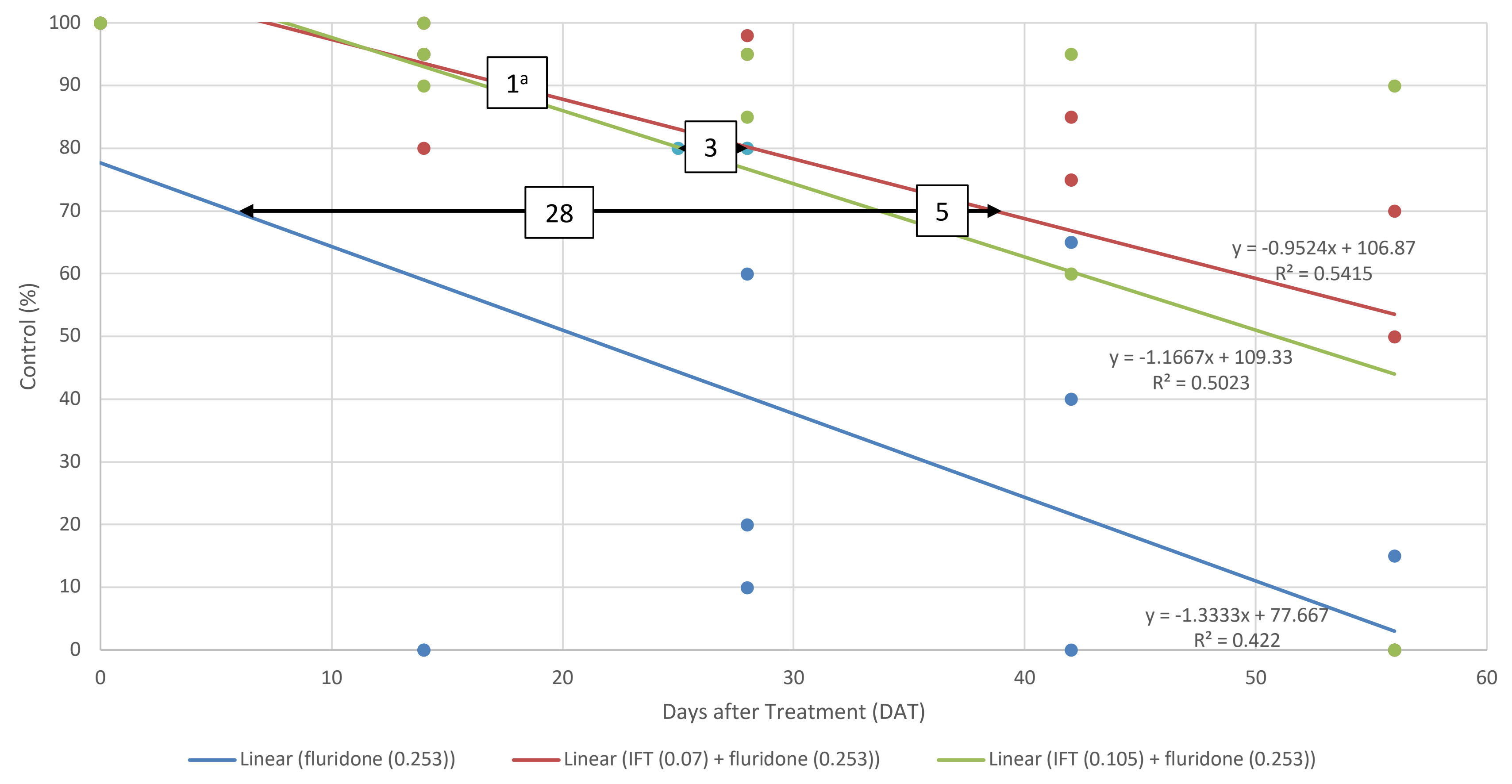
[a] Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.5. Predictive Palmer amaranth control for isoxaflutole plus fluometuron tank-mix combinations in 2021.



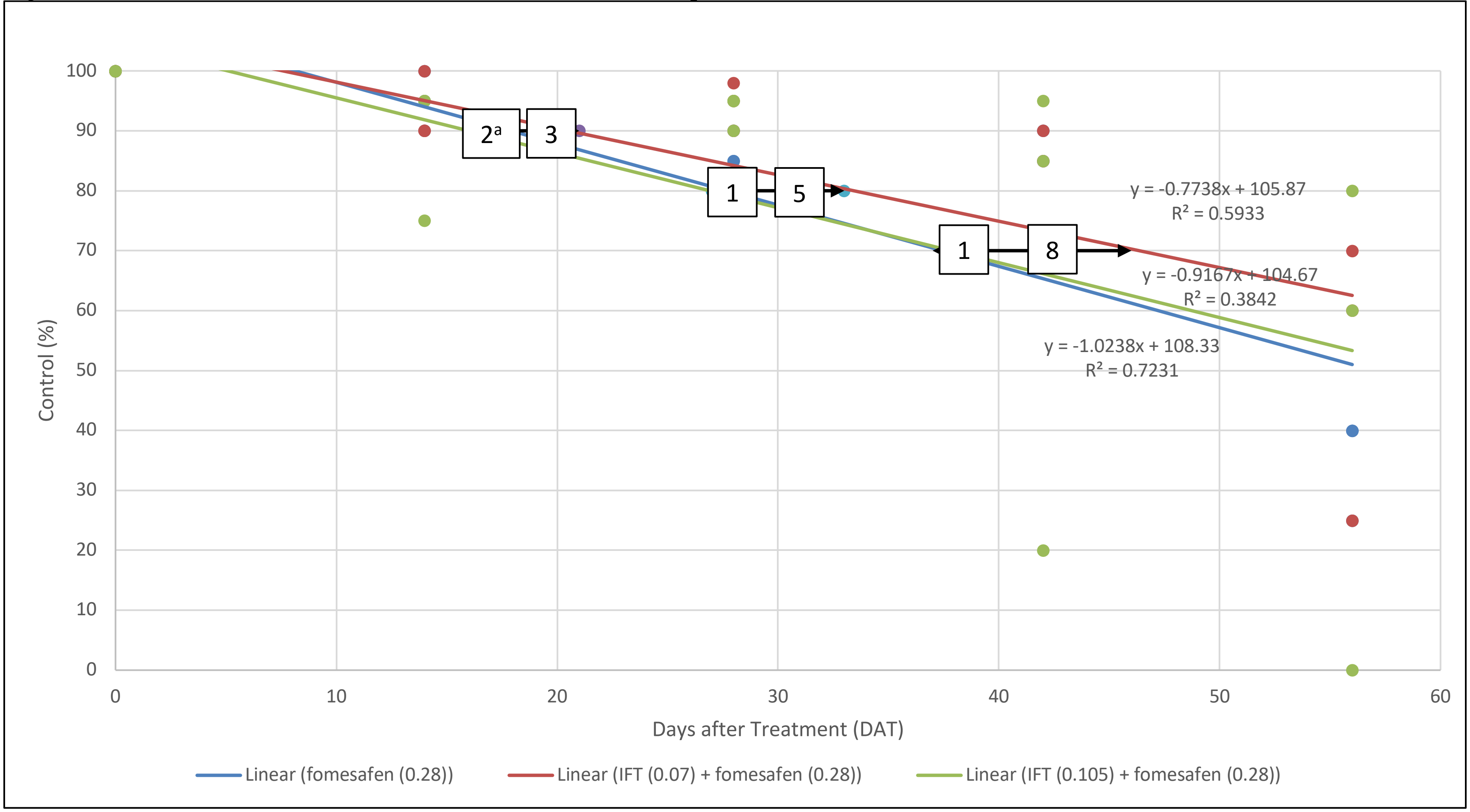
[a] Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.6. Predictive Palmer amaranth control for isoxaflutole plus fluridone tank-mix combinations in 2021.



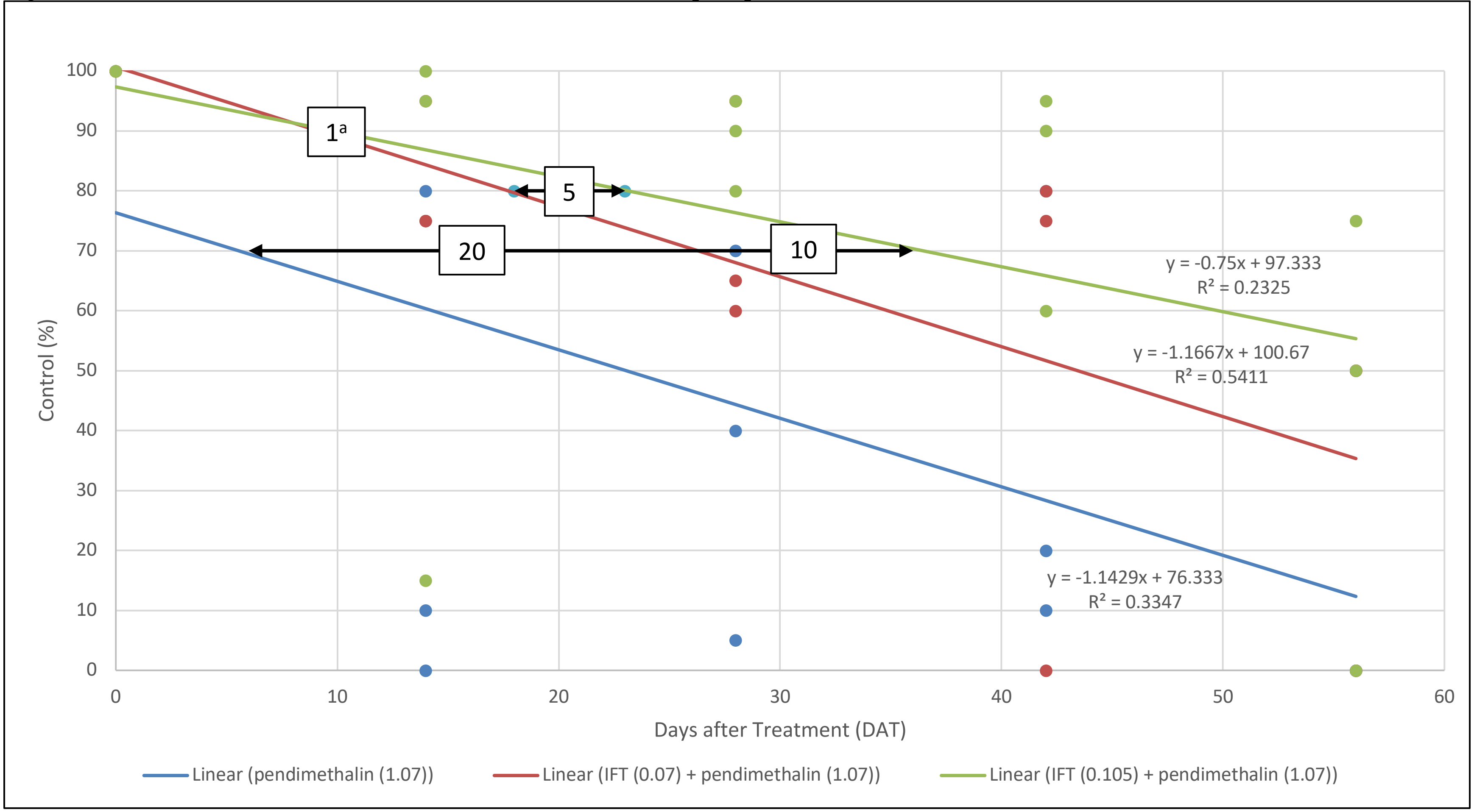
[a] Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.7. Predictive Palmer amaranth control for isoxaflutole plus fomesafen tank-mix combinations in 2021.



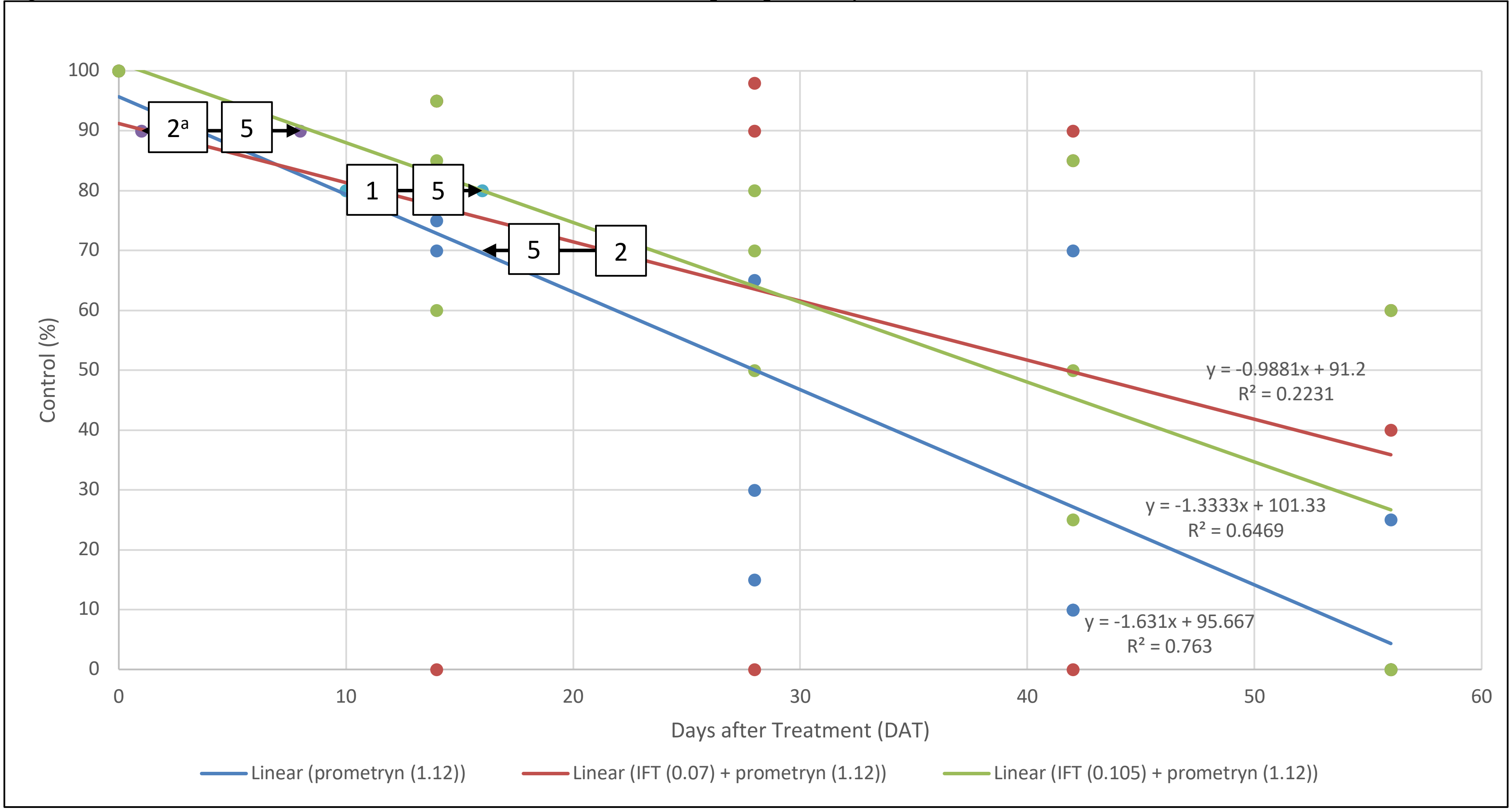
[a] Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.8. Predictive Palmer amaranth control for isoxaflutole plus pendimethalin tank-mix combinations in 2021.



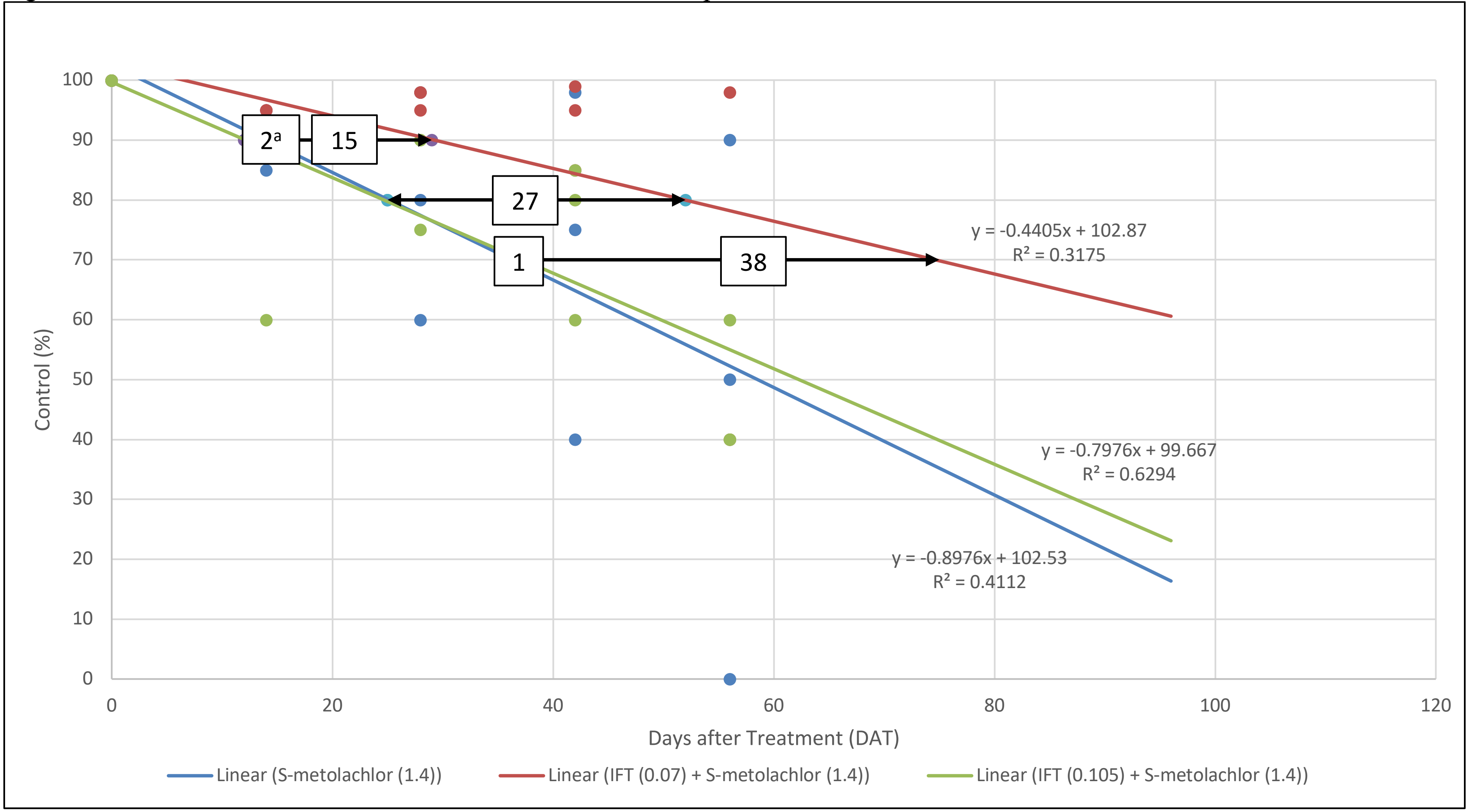
[a] Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.9. Predictive Palmer amaranth control for isoxaflutole plus prometryn tank-mix combinations in 2021.



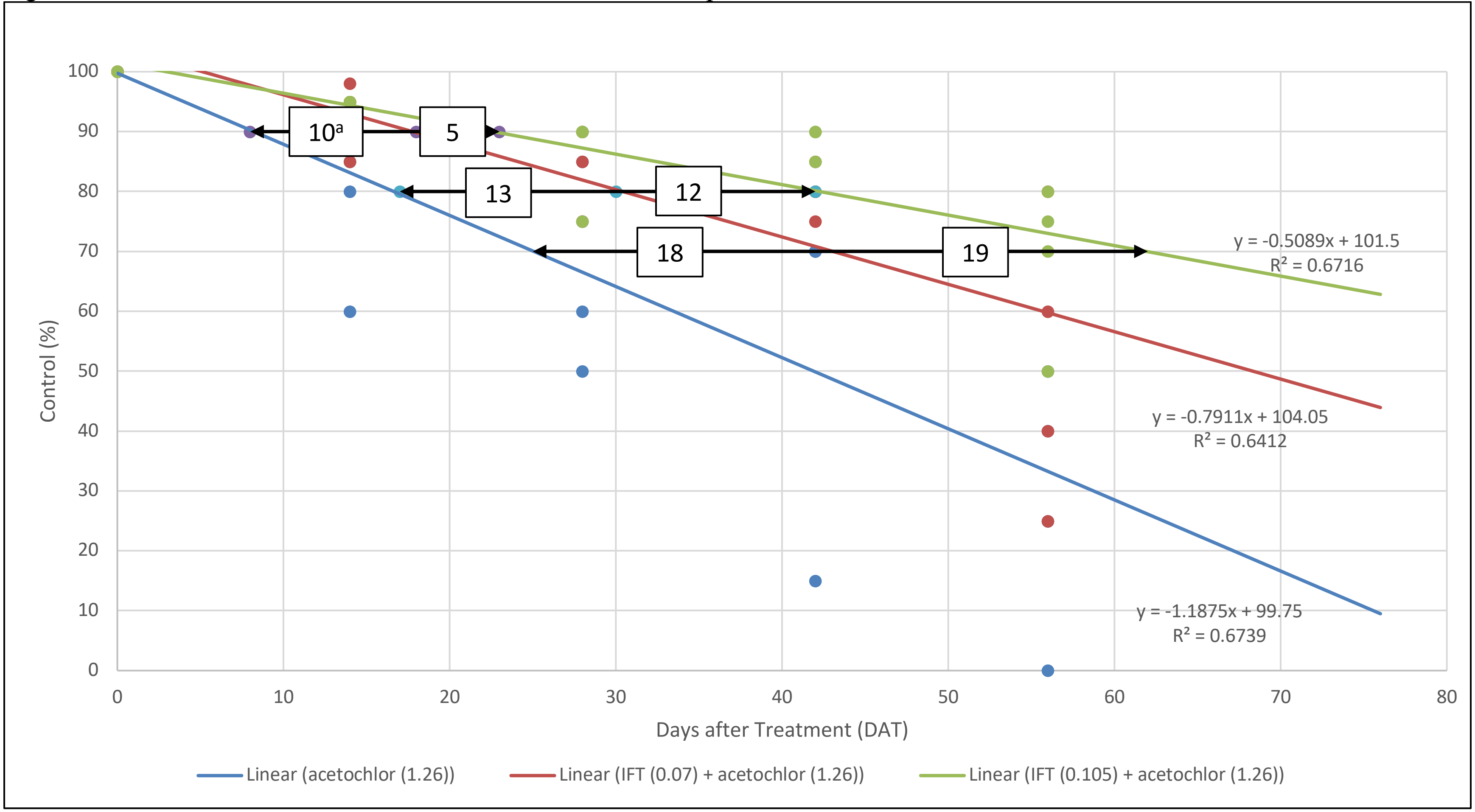
[a]Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.10. Predictive Palmer amaranth control for isoxaflutole plus *S*-metolachlor tank-mix combinations in 2021.



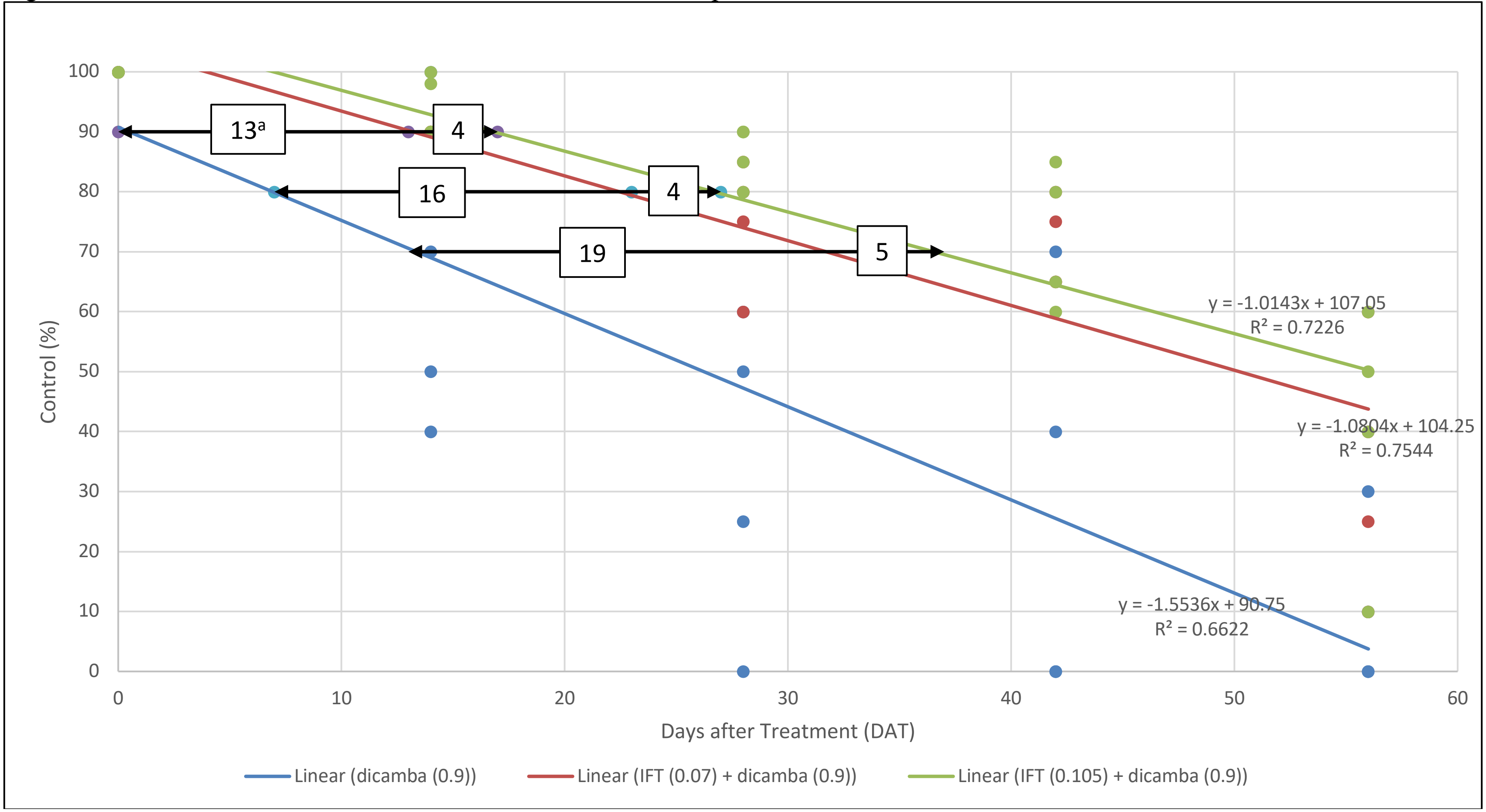
[a]Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.11. Predictive Palmer amaranth control for isoxaflutole plus acetochlor tank-mix combinations in 2022.



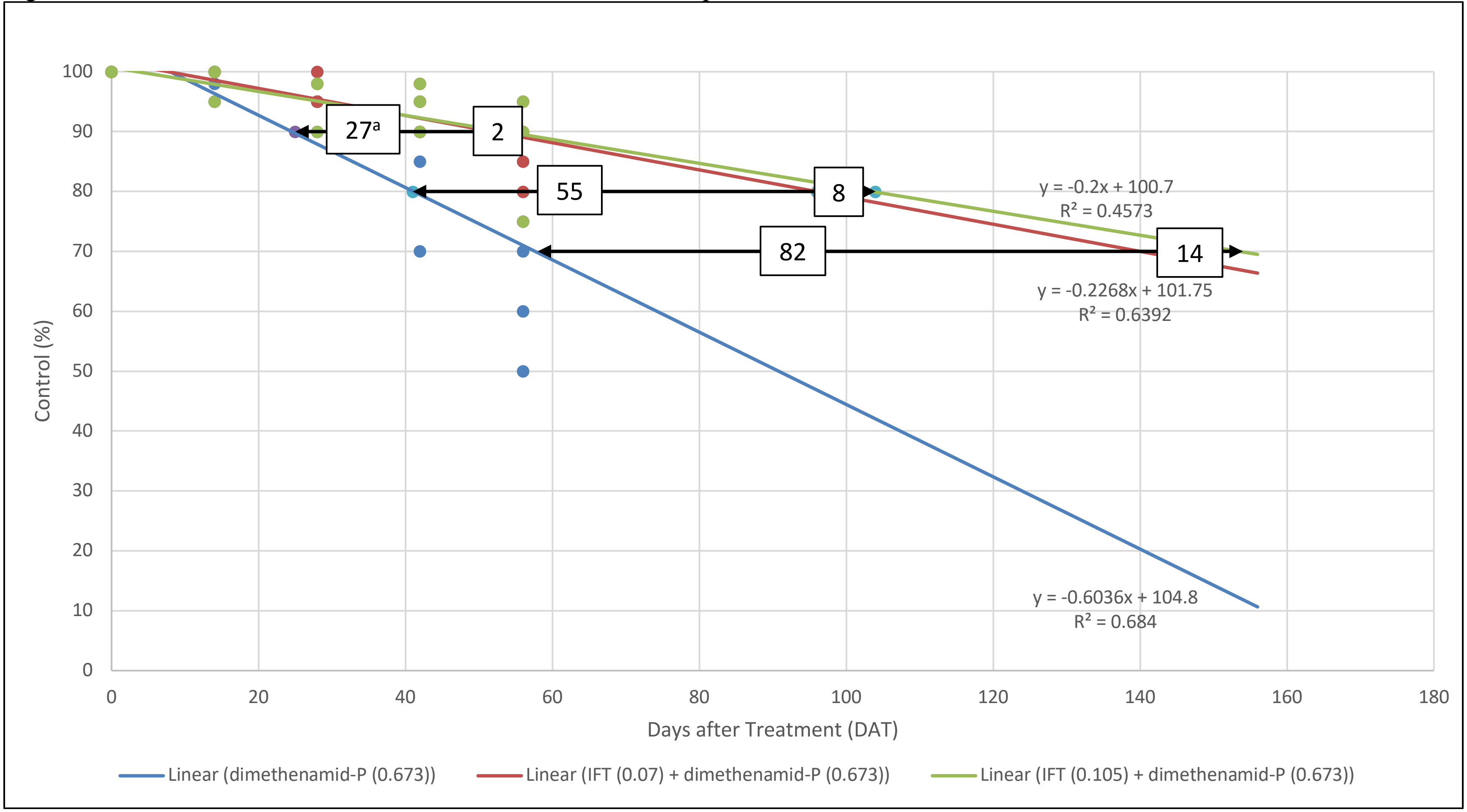
[a]Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.12. Predictive Palmer amaranth control for isoxaflutole plus dicamba tank-mix combinations in 2022.



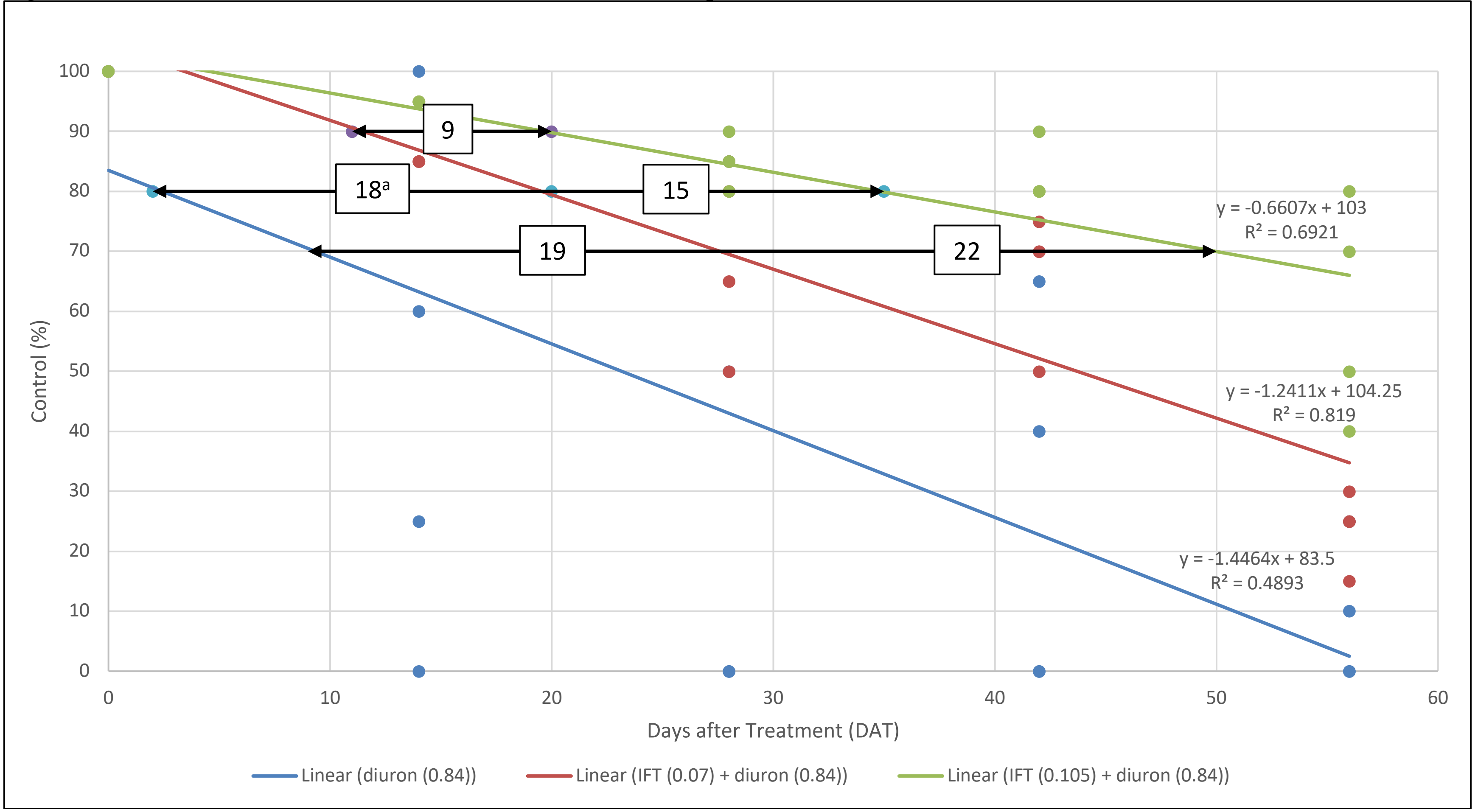
[a] Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.13. Predictive Palmer amaranth control for isoxaflutole plus dimethenamid-P tank-mix combinations in 2022.



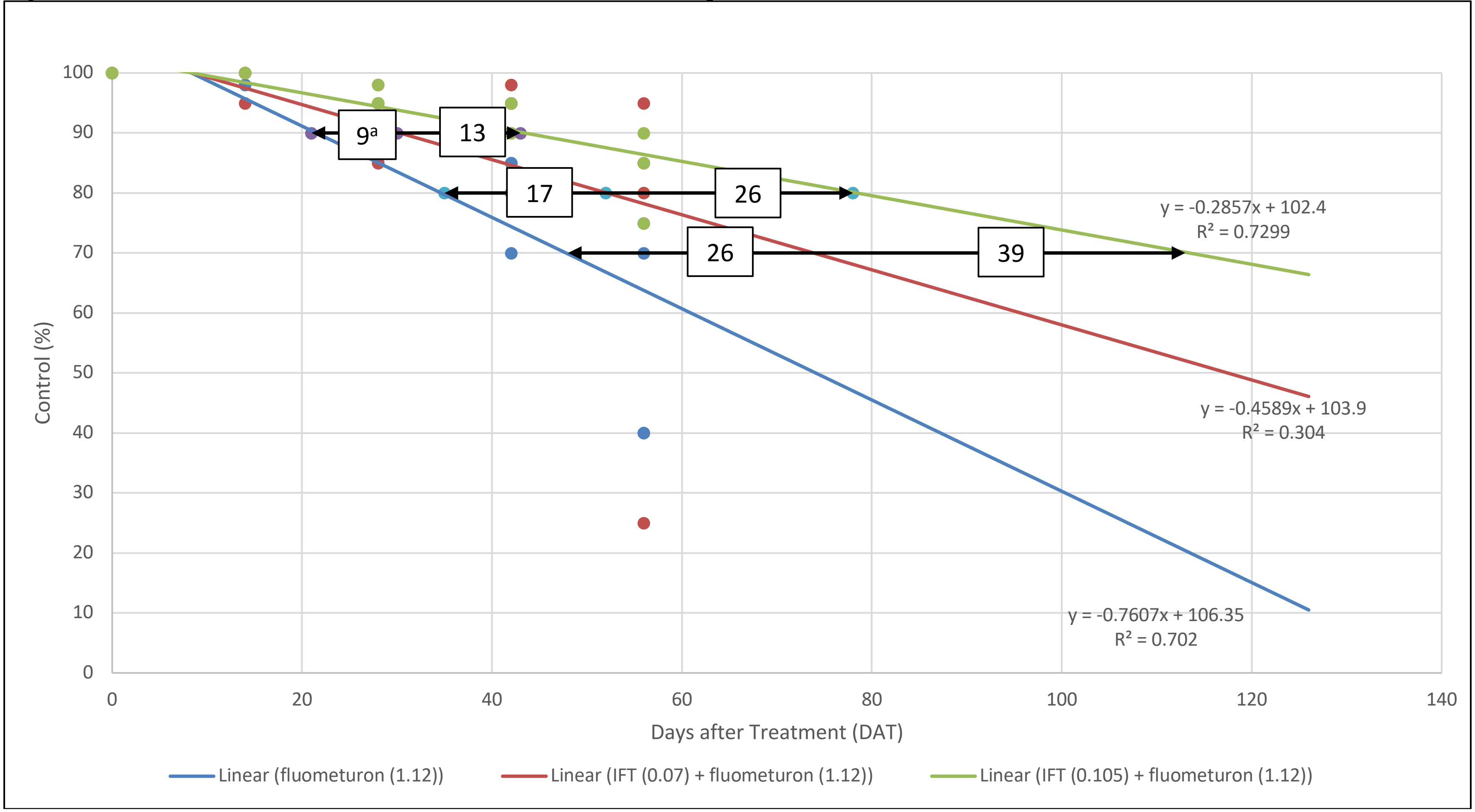
[a] Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.14. Predictive Palmer amaranth control for isoxaflutole plus diuron tank-mix combinations in 2022.



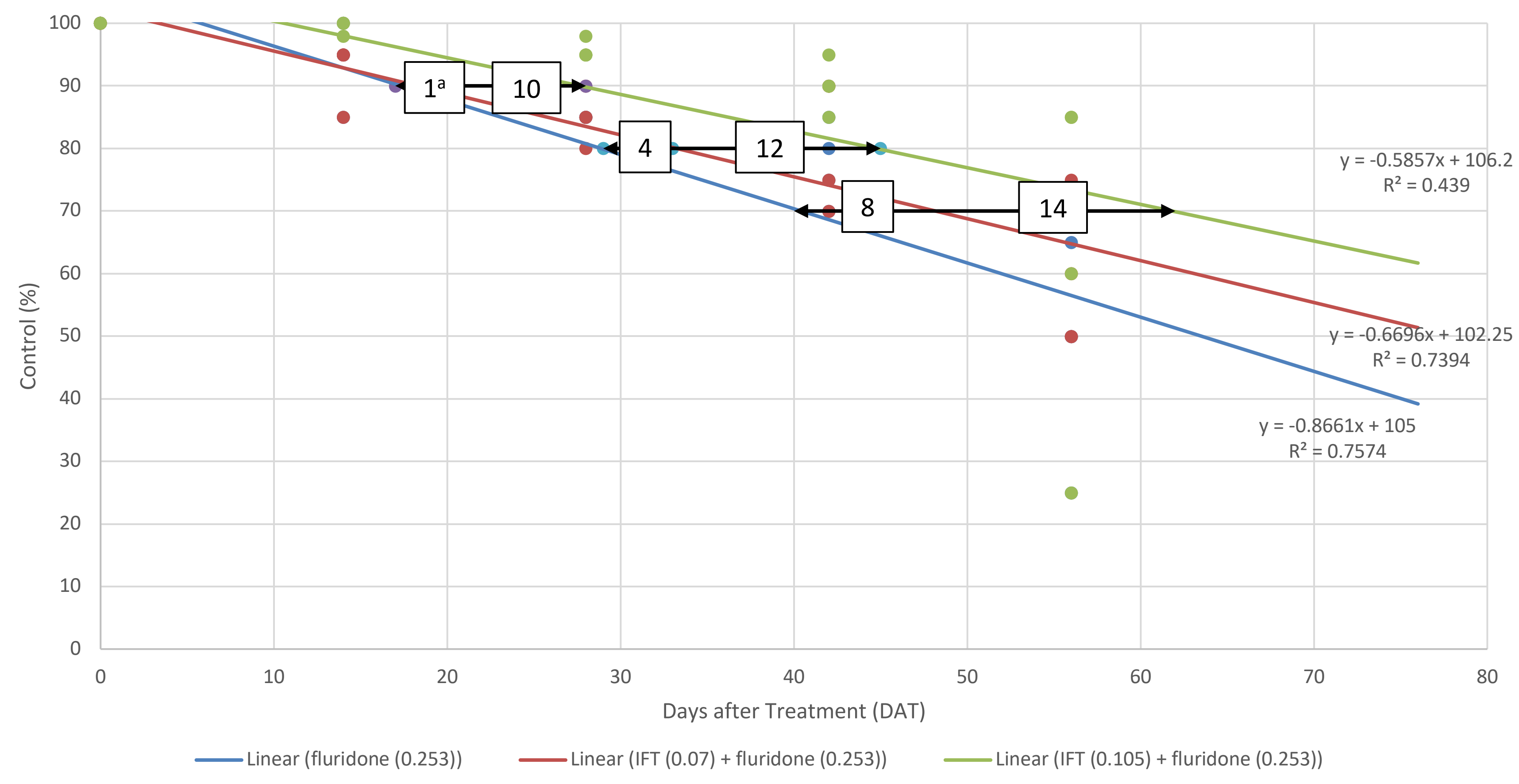
[a]Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.15. Predictive Palmer amaranth control for isoxaflutole plus fluometuron tank-mix combinations in 2022.



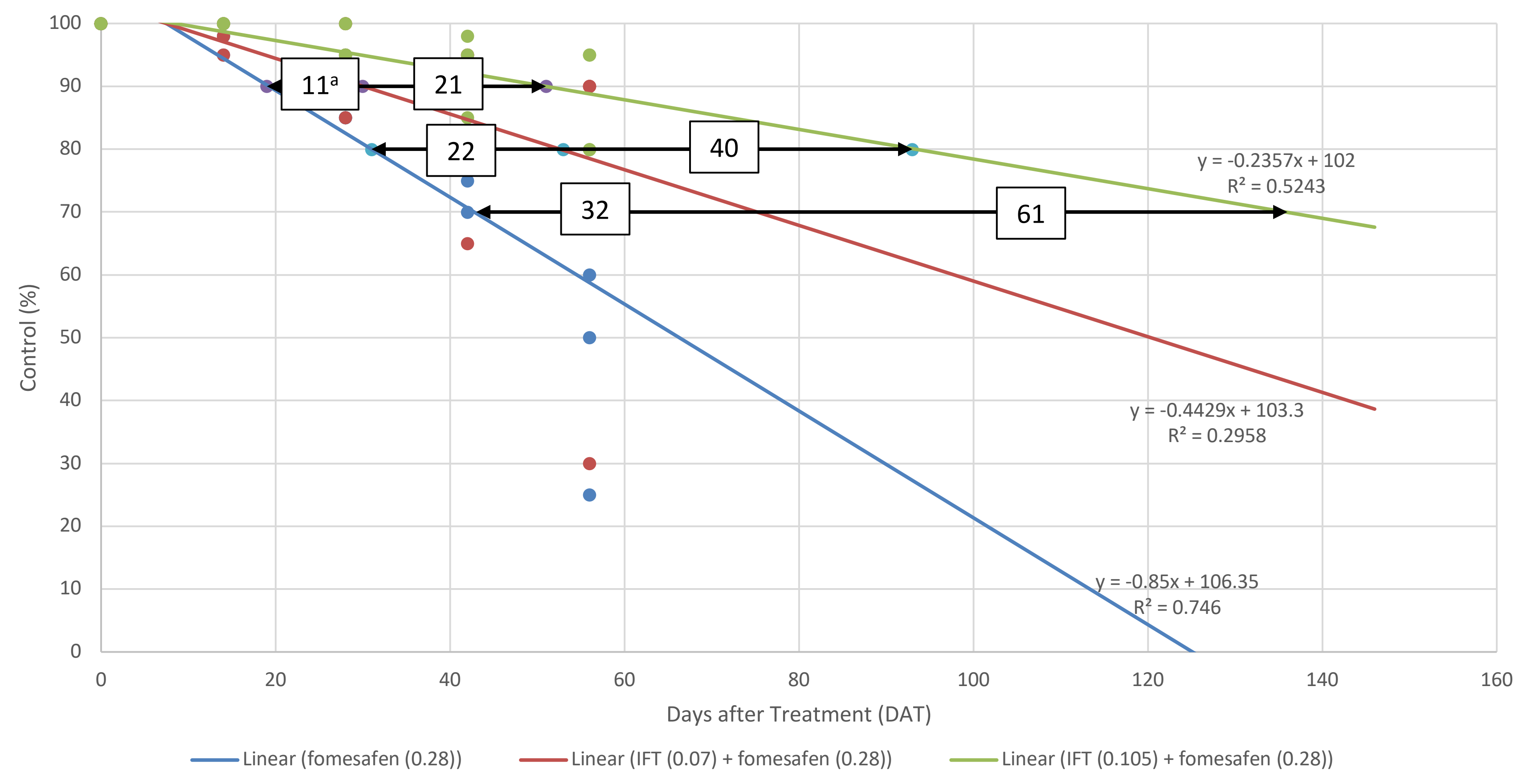
[a]Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.16. Predictive Palmer amaranth control for isoxaflutole plus fluridone tank-mix combinations in 2022.



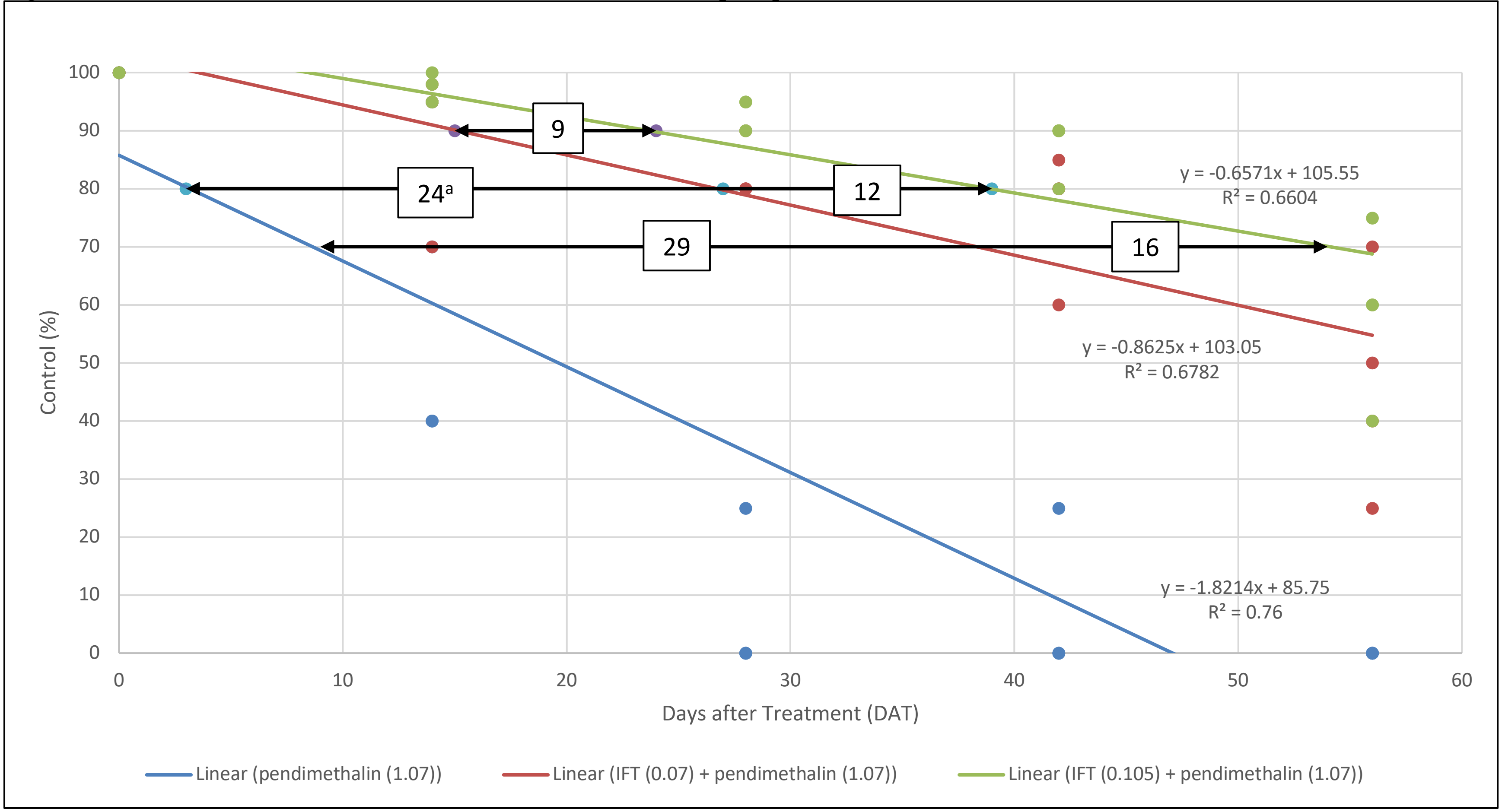
[a] Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.17. Predictive Palmer amaranth control for isoxaflutole plus fomesafen tank-mix combinations in 2022.



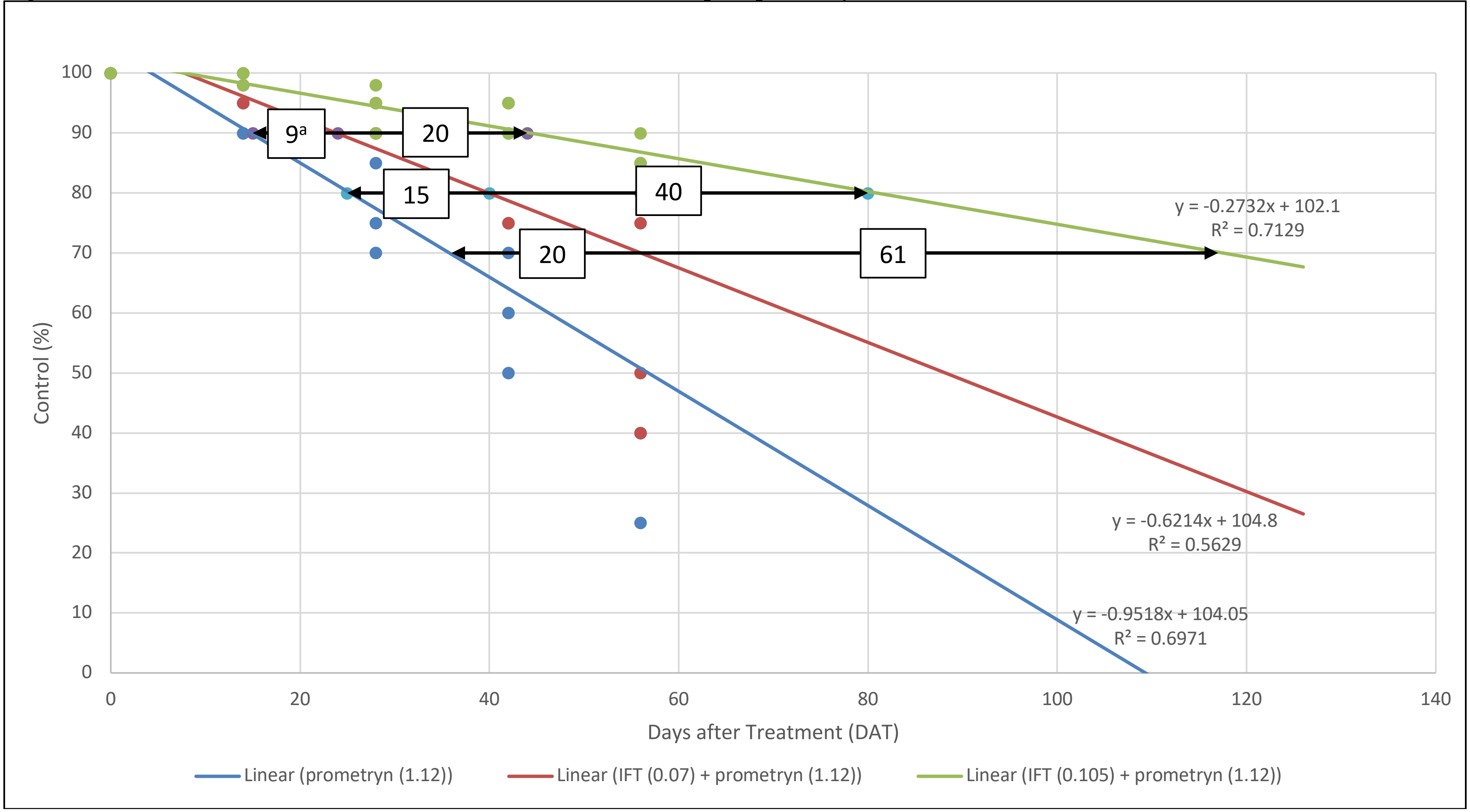
[a]Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.18. Predictive Palmer amaranth control for isoxaflutole plus pendimethalin tank-mix combinations in 2022.



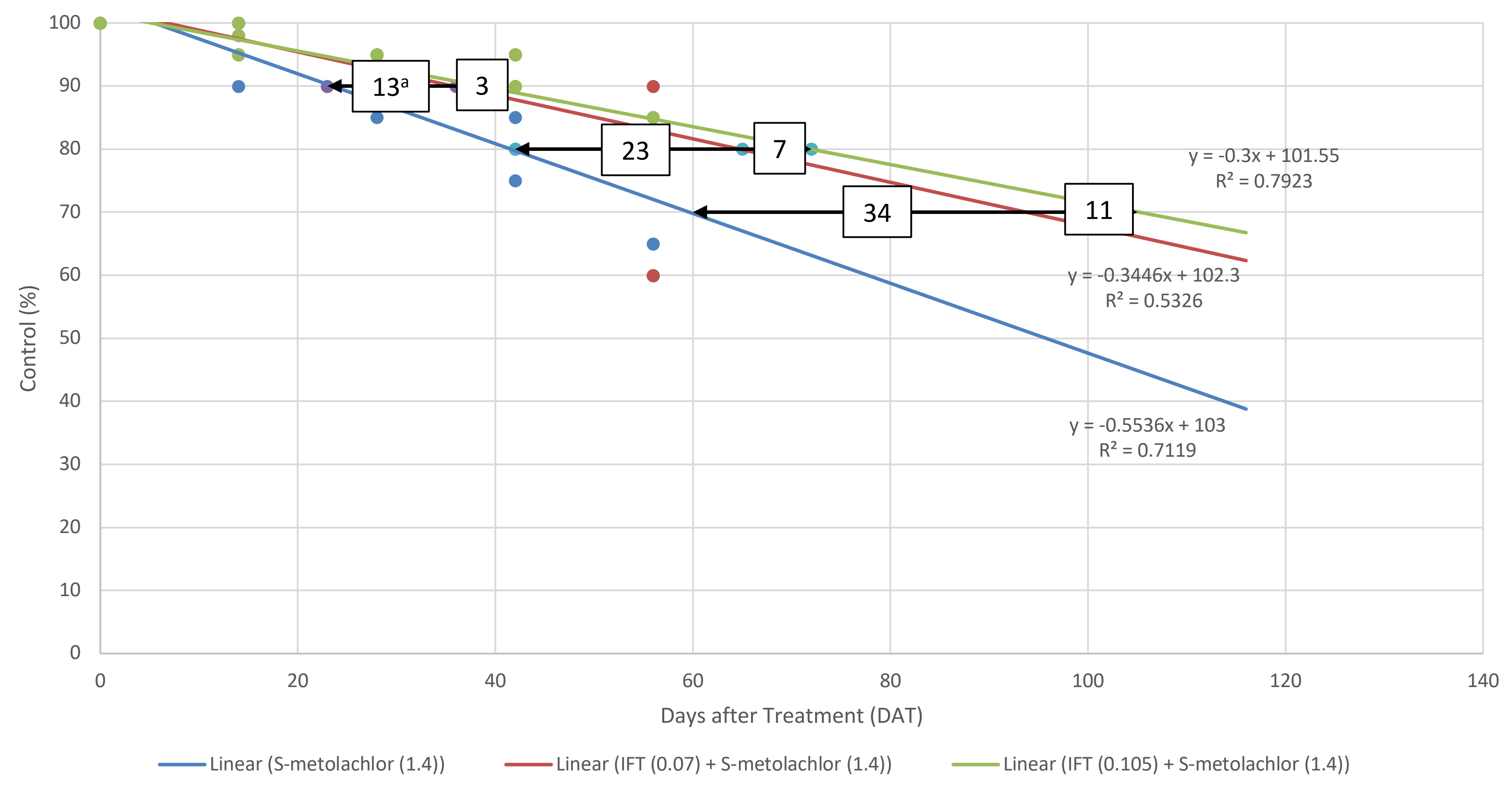
[a]Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.19. Predictive Palmer amaranth control for isoxaflutole plus prometryn tank-mix combinations in 2022.



[a] Numbers in boxes are days of extended control compared to the closest treatment.

Figure 3.20. Predictive Palmer amaranth control for isoxaflutole plus *S*-metolachlor tank-mix combinations in 2022.



[a] Numbers in boxes are days of extended control compared to the closest treatment.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Axant™ Flex cotton provides a new option for producers to control troublesome weeds and combat herbicide resistance. Palmer amaranth resistance to glyphosate, glufosinate, and dicamba has been reported in cotton across the United States (Heap 2023). The ability to use isoxaflutole introduces a novel mode of action to cotton production.

Incorporating isoxaflutole into a cotton weed management system can aid in season-long weed control while also diversifying the system to help delay herbicide-resistance. Soil-residual weed control from isoxaflutole in combination with other soil residual herbicides can help provide the needed 8 week weed-free period at the beginning of the growing season (Buchanan and Burns 1970).

Isoxaflutole used preemergence can aid in Palmer amaranth control and reduce the reliance on postemergence herbicides. When isoxaflutole was applied preemergence, ≥88% Palmer amaranth control was observed in both years of the in-crop study 28 days after the early-postemergence application. These early-postemergence applications were effective with the dicamba-based and the glufosinate-based systems if isoxaflutole was included in the preemergence application.

Isoxaflutole plus other preemergence soil residual herbicides can extend the duration of Palmer amaranth control. The duration of control was extended in both years when isoxaflutole was added to acetochlor, dicamba, diuron, fluometuron, pendimethalin, and prometryn the duration of control was extended in both years. With this extension of control, the need for a postemergence application can be delayed, providing more flexibility for timely and effective postemergence applications.

Axant™ Flex cotton and the use of isoxaflutole can be important tools to aid in season-long weed control, but they must be managed properly to be successful. Moving forward, it will be important to manage this herbicide trait in a responsible manner to delay cases of herbicide-resistance. Using multiple modes of action of herbicides, physical control of weeds, and diversification of weed management will all be important tools to make this technology effective and sustainable (Norsworthy et al. 2012).

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Norsworthy JK, Ward SM, Shaw DR, Llewellyn RS, Nichols RL, Webster TM, Bradley KW, Frisvold G, Powles SB, Burgos NR, Witt WW, Barrett M (2012) Reducing the risks of herbicide resistance: best management practices and recommendations. Weed Sci. 60: 31-62.