Noncrop and Industrial Vegetation Management Weed Science

2004 Annual Research Report

UNIVERSITY OF KENTUCKY
College of Agriculture
Department of Agronomy

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INFORMATION NOTE 2005 NCVM-1

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The information provided in this document represents a collaborative effort between the Roadside Environment Branch of the Kentucky Transportation Cabinet and the Department of Agronomy in the College of Agriculture at the University of Kentucky. The main priority of this project was to collect and disseminate information to the KTC REB to increase the efficiency of operations aimed at roadside environment management.

This report contains a summary of research conducted during 2004. This document is primarily for the use of the Kentucky Transportation Cabinet. Other use is allowable given proper credit to the authors.

Weather data was obtained from weather recorders located on site of the Princeton Agricultural Research Station in Princeton, KY (located in western Kentucky) and the Spindletop Agricultural Research Station in Lexington, KY (located in central Kentucky).

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This work was accomplished with the help of Garrick Howell, a student at UK, who aided in study initiation, data collection and mining, and plot maintenance. Personnel in the Weed Science group who also aided in this project in terms of labor, equipment, and ideas include Sara Carter, Ted Hicks, Jack Zeleznik, Charlie Slack, Joey Buckles, Don Breeden, Dr. J.D. Green, and Dr. Jim Martin. Appreciation is also given to the farm crews at both Spindletop and Princeton Research Stations for equipment and plot maintenance.

Research was also conducted with the aid of Mark McLemore and his staff at KenLake State Park who allowed the use of land area to conduct kudzu research. Darrell Simpson, formally of the UK Cooperative Extension Service in Muhlenberg County, KY, also provided land area to perform Johnsongrass research.

The research could not have been accomplished if not for the generous contributions of product. Contributors of product used include:

Allegare, LLC
BASF Corporation
Brewer International
CWC Chemical, Inc
Dow AgroSciences
DuPont
Miller Chemical
PBI Gordon
Riverdale / NuFarm Inc
Townsend Chemical

Estimated prices for products used in this research were obtained with the help of CWC Chemical, Inc., Townsend Chemical, Ryan’s Agri & Pest Supplies located in Lexington, KY, and Woodford Feed Company, Inc., located in Versailles, KY.

We sincerely appreciate the effort and continued support of all our cooperators and look forward to future endeavors.

Species List

Scientific Name	Common Name
Andropogon virginicus L.	Broomsedge
Aster pilosus Willd.	White Heath Aster
Chenopodium album L.	Common Lambsquarters
Cirsium arvense (L.) Scop.	Canada Thistle
Conuza Canadensis (L.) Cronq.	Marestail
Dactylis glomerata L.	Orchardgrass
Daucus carota L.	Wild Carrot
Digitaria sanguinalis (L.) Scop.	Crabgrass
Festuca arundinacea Schreb.	Tall Fescue
Lespedeza cuneata Dumont	Serecia Lespedeza
Plantago lanceolata L.	Buckhorn Plantain
Polygonum cuspidatum Sieb. & Zucc.	Japanese Knotweed
Pueraria lobata (Willd.) Ohwi	Kudzu
Rumex crispus L.	Curly Dock
Setaria glauca (L.) Beauv.	Yellow Foxtail
Sorghum halepense (L.) Pers.	Johnsongrass
Taraxacum officinale Weber in Wiggers	Dandelion
Trifolium pretense L.	Red Clover
Trifolium repens L.	White Clover

Princeton Weather Data 2004

STATION	DATE	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	EVAP
Princeton	04-01-2004	53	35	44	0.10	100	60	53	50			
Princeton	04-02-2004	61	33	47		100	30	55	50			
Princeton	04-03-2004	67	34	50		100	20	56	52			
Princeton	04-04-2004	62	30	46		100	28	55	51			
Princeton	04-05-2004	62	30	46		100	28	55	51			
Princeton	04-06-2004	71	35	53		100	28	57	52			
Princeton	04-07-2004	79	46	62		100	30	59	54			
Princeton	04-08-2004	73	46	60		100	20	61	54			
Princeton	04-09-2004	71	38	54		100	28	60	54			
Princeton	04-10-2004	70	53	62		54	40	59	55			
Princeton	04-11-2004	61	49	55	0.04	100	50	53	52			
Princeton	04-12-2004	49	42	46	0.97	100	85	53	52			
Princeton	04-13-2004	49	34	42	0.56	100	70	48	48			
Princeton	04-14-2004	63	34	48	0.05	90	30	52	50			
Princeton	04-15-2004	73	35	54		100	28	55	51			
Princeton	04-16-2004	77	53	65		64	42	60	54			
Princeton	04-17-2004	82	58	70		100	45	59	53			
Princeton	04-18-2004	84	59	72		95	40	60	58			
Princeton	04-19-2004	82	65	74	T	100	80	63	59			
Princeton	04-20-2004	82	59	70		100	42	66	64			
Princeton	04-21-2004	82	60	71	0.13	100	64	65	64			
Princeton	04-22-2004	74	54	64	0.37	100	85	65	63			
Princeton	04-23-2004	75	54	64	0.98	100	100	65	64			
Princeton	04-24-2004	79	56	68		100	70	66	63			
Princeton	04-25-2004	74	62	68	1.07	100	60	66	65			
Princeton	04-26-2004	71	45	58		100	32	65	65			
Princeton	04-27-2004	73	42	58		100	20	65	65			
Princeton	04-28-2004	76	42	59		95	32	65	64			
Princeton	04-29-2004	78	56	67		70	35	65	65			
Princeton	04-30-2004	78	61	70	1.05	100	70	66	66			

Summary for Princeton for the period 4-1-2004 through 4-30-2004:

STATION	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	TOTAL PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	TOTAL EVAP
Princeton	71	47	59	5.32	96	46	60	57			
(Deviation from normal)	-0	+0	+0	+0.52							

STATION	DATE	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	EVAP
Princeton	05-01-2004	71	58	64	0.22	100	70	65	64			
Princeton	05-02-2004	69	46	58	0.30	100	30	66	65			
Princeton	05-03-2004	62	44	53	0.19	100	55	65	61			
Princeton	05-04-2004	69	40	54		100	38	65	63			
Princeton	05-05-2004	81	57	69		100	48	66	66			
Princeton	05-06-2004	83	60	72		100	40	65	65			
Princeton	05-07-2004	85	60	72		100	38	65	65			
Princeton	05-08-2004	86	56	71		95	40	66	65			
Princeton	05-09-2004	85	62	74		100	45	66	65			
Princeton	05-10-2004	84	61	72	0.12	100	50	65	65			
Princeton	05-11-2004	84	62	73	T	100	50	72	72			
Princeton	05-12-2004	84	65	74		100	48	72	72			
Princeton	05-13-2004	84	66	75	0.62	100	72	72	72			
Princeton	05-14-2004	74	67	70	0.44	100	96	72	72			
Princeton	05-15-2004	70	54	62	0.89	100	100	71	66			
Princeton	05-16-2004	74	58	66		100	85	72	68			
Princeton	05-17-2004	81	65	73		100	72	71	71			
Princeton	05-18-2004	83	65	74		100	64	72	72			
Princeton	05-19-2004	84	66	75		100	66	71	71			
Princeton	05-20-2004	88	68	78		100	58	71	71			
Princeton	05-21-2004	88	70	79		100	56	71	71			
Princeton	05-22-2004	87	70	78		100	50	71	71			
Princeton	05-23-2004	84	71	78		100	55	71	71			
Princeton	05-24-2004	85	71	78		100	72	71	71			
Princeton	05-25-2004	89	68	78	T	100	70	71	71			
Princeton	05-26-2004	83	68	76	1.58	100	70	71	71			
Princeton	05-27-2004	85	65	75	0.27	100	75	71	71			
Princeton	05-28-2004	85	65	75	0.32	100	60	71	71			
Princeton	05-29-2004	84	64	74		100	70	72	71			
Princeton	05-30-2004	86	70	78	0.08	100	75	71	71			
Princeton	05-31-2004	86	64	75	2.31	100	35	71	71			

Summary for Princeton for the period 5-1-2004 through 5-31-2004:

STATION	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	TOTAL PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	TOTAL EVAP
Princeton	81	62	72	7.34	100	60	69	69			
(Deviation from normal)	+1	+6	+3	+2.38							

STATION	DATE	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	EVAP
Princeton	06-01-2004	85	55	70		100	40	71	71			
Princeton	06-02-2004	86	62	74	0.04	100	36	71	71			
Princeton	06-03-2004	86	61	74		100	30	71	71			
Princeton	06-04-2004	78	60	69		100	40	71	71			
Princeton	06-05-2004	81	57	69		100	35	71	71			
Princeton	06-06-2004	76	60	68		100	60	71	71			
Princeton	06-07-2004	85	62	74		100	56	71	71			
Princeton	06-08-2004	90	68	79		100	46	71	71			
Princeton	06-09-2004	90	70	80		100	50	71	71			
Princeton	06-10-2004	89	67	78	0.33	100	70	71	71			
Princeton	06-11-2004	90	71	80	0.25	100	60	71	71			
Princeton	06-12-2004	91	67	79	1.01	100	65	71	71			
Princeton	06-13-2004	86	68	77	0.74	100	75	71	71			
Princeton	06-14-2004	86	69	78		100	70	71	71			
Princeton	06-15-2004	88	68	78	0.11	100	82	71	71			
Princeton	06-16-2004	88	73	80	0.30	100	70	71	71			
Princeton	06-17-2004	88	72	80	0.01	100	70	71	71			
Princeton	06-18-2004	89	69	79	0.16	100	46	71	71			
Princeton	06-19-2004	88	58	73	0.13	100	50	73	72			
Princeton	06-20-2004	77	58	68		100	35	75	72			
Princeton	06-21-2004	83	58	70		100	56	71	71			
Princeton	06-22-2004	83	57	70	0.21	100	74	71	71			
Princeton	06-23-2004	83	63	73	0.06	100	54	71	71			
Princeton	06-24-2004	83	60	72		100	58	71	71			
Princeton	06-25-2004	84	69	76	0.05	100	80	71	71			
Princeton	06-26-2004	79	63	71		100	37	71	71			
Princeton	06-27-2004	81	55	68		100	35	70	69			
Princeton	06-28-2004	83	60	72		100	44	68	68			
Princeton	06-29-2004	84	63	74		100	52	68	68			
Princeton	06-30-2004	87	63	75		100	52	69	69			

Summary for Princeton for the period 6-1-2004 through 6-30-2004:

STATION	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	TOTAL PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	TOTAL EVAP
Princeton	85	64	74	3.40	100	54	71	71			
(Deviation from normal)	-2	+0	-1	-0.45							

STATION	DATE	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	EVAP
Princeton	07-01-2004	86	63	74	0.05	100	88	69	69			
Princeton	07-02-2004	84	69	76	0.09	100	80	58	58			
Princeton	07-03-2004	86	72	79		100	70	60	58			
Princeton	07-04-2004	90	71	80		100	60	59	58			
Princeton	07-05-2004	87	69	78	0.52	100	85	59	58			
Princeton	07-06-2004	88	68	78	0.50	100	74	58	58			
Princeton	07-07-2004	84	65	74	0.88	100	50	58	58			
Princeton	07-08-2004 E	85	62	74		100	48	78	76			
Princeton	07-09-2004	90	71	80		100	60	85	85			
Princeton	07-10-2004	90	70	80		100	55	84	83			
Princeton	07-11-2004	89	70	80		100	65	86	85			
Princeton	07-12-2004	93	73	83		100	52	82	82			
Princeton	07-13-2004	95	74	84		100	52	85	85			
Princeton	07-14-2004	95	66	80	0.22	100	48	84	83			
Princeton	07-15-2004	86	64	75		100	40	84	82			
Princeton	07-16-2004	85	62	74		100	64	85	83			
Princeton	07-17-2004	84	62	73	0.47	100	65	84	83			
Princeton	07-18-2004	84	65	74		100	45	85	84			
Princeton	07-19-2004	85	59	72		100	40	84	80			
Princeton	07-20-2004	87	58	72		100	48	84	81			
Princeton	07-21-2004	88	70	79		100	68	85	81			
Princeton	07-22-2004	91	74	82		100	64	85	83			
Princeton	07-23-2004	92	68	80	0.04	100	54	85	85			
Princeton	07-24-2004	88	69	78	0.06	100	70	85	83			
Princeton	07-25-2004	83	66	74	0.04	100	95	84	83			
Princeton	07-26-2004	72	62	67	0.03	100	100	85	75			
Princeton	07-27-2004	78	55	66		100	42	85	78			
Princeton	07-28-2004	82	53	68		100	40	85	79			
Princeton	07-29-2004	82	53	68		100	52	85	78			
Princeton	07-30-2004	81	52	66	1.97	100	82	85	77			
Princeton	07-31-2004	82	52	67		100	70	85	80			

Summary for Princeton for the period 7-1-2004 through 7-31-2004:

STATION	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	TOTAL PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	TOTAL EVAP
Princeton	86	65	75	4.87	100	62	79	76			
(Deviation from normal)	-3	-1	-2	+0.58							

STATION	DATE	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	EVAP
Princeton	08-01-2004	86	62	74		100	45	85	81			
Princeton	08-02-2004	87	65	76		100	46	85	82			
Princeton	08-03-2004	91	64	78		100	52	85	83			
Princeton	08-04-2004	91	72	82		100	68	85	82			
Princeton	08-05-2004	87	68	78	1.20	100	56	85	79			
Princeton	08-06-2004	80	57	68		100	36	85	79			
Princeton	08-07-2004	79	53	66		100	40	84	78			
Princeton	08-08-2004	85	55	70		100	45	85	78			
Princeton	08-09-2004	86	67	76		100	50	84	79			
Princeton	08-10-2004	84	69	76		100	49	85	80			
Princeton	08-11-2004	88	57	72		100	60	85	77			
Princeton	08-12-2004	70	55	62	0.06	100	45	85	74			
Princeton	08-13-2004	72	50	61		100	40	84	74			
Princeton	08-14-2004	72	47	60		100	30	84	76			
Princeton	08-15-2004	78	49	64		100	35	85	74			
Princeton	08-16-2004	82	50	66		100	28	83	75			
Princeton	08-17-2004	82	53	68		100	36	85	80			
Princeton	08-18-2004	91	65	78		100	44	84	77			
Princeton	08-19-2004	91	65	78		100	42	84	79			
Princeton	08-20-2004	90	69	80	0.46	100	80	85	75			
Princeton	08-21-2004	81	64	72	0.25	100	45	84	76			
Princeton	08-22-2004	84	58	71		100	45	84	79			
Princeton	08-23-2004	87	63	75	0.17	100	58	85	77			
Princeton	08-24-2004	86	62	74	0.04	100	68	85	78			
Princeton	08-25-2004	87	68	78	0.62	100	70	85	78			
Princeton	08-26-2004	91	74	82		100	62	85	80			
Princeton	08-27-2004	91	69	80	T	100	56	80	80			
Princeton	08-28-2004	87	72	80	T	100	90	80	78			
Princeton	08-29-2004	81	68	74	0.22	100	70	80	78			
Princeton	08-30-2004	77	65	71		100	58	80	77			

Summary for Princeton for the period 8-1-2004 through 8-30-2004:

STATION	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	TOTAL PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	TOTAL EVAP
Princeton	84	62	73	3.02	100	52	84	78			
(Deviation from normal)	-3	-2	-3	-0.86							

STATION	DATE	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	EVAP
Princeton	09-01-2004	83	60	72		100	36	80	77			
Princeton	09-02-2004	83	62	72		100	60	80	77			
Princeton	09-03-2004	83	65	74		100	61	81	77			
Princeton	09-04-2004 E	85	65	75		99	66	76	75			
Princeton	09-05-2004	89	64	76		100	45	81	79			
Princeton	09-06-2004	91	68	80		100	41	80	80			
Princeton	09-07-2004	87	66	76		100	60	81	78			
Princeton	09-08-2004	77	62	70		90	56	80	75			
Princeton	09-09-2004	82	56	69		100	40	81	76			
Princeton	09-10-2004	83	54	68		100	33	80	76			
Princeton	09-11-2004	87	57	72		100	34	80	77			
Princeton	09-12-2004	84	62	73		100	50	81	76			
Princeton	09-13-2004	84	64	74		100	44	80	75			
Princeton	09-14-2004	87	66	76		100	46	80	77			
Princeton	09-15-2004	89	66	78		100	46	80	78			
Princeton	09-16-2004 E	83	67	75	0.07	98	42	75	74			
Princeton	09-17-2004 E	83	66	74	0.13	98	78	72	72			
Princeton	09-18-2004	84	51	68		100	18	80	76			
Princeton	09-19-2004	83	54	68		100	25	81	75			
Princeton	09-20-2004	84	48	66		100	18	76	74			
Princeton	09-21-2004	85	52	68		100	27	76	74			
Princeton	09-22-2004	86	50	68		100	18	76	75			
Princeton	09-23-2004	85	55	70		100	28	76	74			
Princeton	09-24-2004	83	63	73		100	48	76	74			
Princeton	09-25-2004	82	65	74		100	32	77	77			
Princeton	09-26-2004	81	55	68		100	35	77	76			
Princeton	09-27-2004	81	53	67		100	36	76	74			
Princeton	09-28-2004	81	56	68		96	28	76	72			
Princeton	09-29-2004	80	48	64		100	32	76	72			
Princeton	09-30-2004 E	75	43	59		100	38	69	67			

Summary for Princeton for the period 9-1-2004 through 9-30-2004:

STATION	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	TOTAL PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	TOTAL EVAP
Princeton	84	59	71	0.20	99	41	78	75			
(Deviation from normal)	+2	+1	+2	-3.13							

Spindletop Weather Data 2004

STATION	DATE	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	EVAP
Spindletop	04-01-2004	51	39	45		90	50	51	48	52	46	
Spindletop	04-02-2004	51	37	44	0.08	94	68	48	47	49	46	
Spindletop	04-03-2004	61	38	50		93	29	53	46	55	45	
Spindletop	04-04-2004	47	33	40		68	36	50	46	50	44	
Spindletop	04-05-2004	53	27	40		77	19	52	43	54	41	
Spindletop	04-06-2004	64	34	49		55	30	54	45	58	43	
Spindletop	04-07-2004	74	50	62		54	32	58	50	62	50	
Spindletop	04-08-2004	72	48	60		68	22	59	54	64	55	
Spindletop	04-09-2004	61	39	50		88	44	58	51	62	51	
Spindletop	04-10-2004	62	45	54		64	34	58	52	63	53	
Spindletop	04-11-2004	59	48	54		72	52	57	53	61	54	
Spindletop	04-12-2004	50	40	45	0.83	100	63	54	49	57	49	
Spindletop	04-13-2004	40	34	37	0.57	100	100	49	46	49	45	
Spindletop	04-14-2004	57	35	46	0.02	100	35	51	45	55	43	
Spindletop	04-15-2004	67	40	54		70	29	56	47	60	45	
Spindletop	04-16-2004	74	50	62		67	34	59	51	62	51	
Spindletop	04-17-2004	77	55	66		64	46	61	54	66	54	
Spindletop	04-18-2004	80	60	70		70	33	62	57	69	58	
Spindletop	04-19-2004	71	62	66		86	47	60	58	64	60	
Spindletop	04-20-2004	74	57	66		96	51	61	58	66	59	
Spindletop	04-21-2004	67	55	61	0.53	96	56	60	59	62	59	
Spindletop	04-22-2004	67	55	61	0.48	97	83	59	57	63	57	
Spindletop	04-23-2004	65	54	60	0.32	97	83	60	58	64	61	
Spindletop	04-24-2004	67	48	58		97	59	61	57	64	57	
Spindletop	04-25-2004	74	58	66	0.20	95	67	62	59	67	59	
Spindletop	04-26-2004	63	48	56		93	46	62	59	66	58	
Spindletop	04-27-2004	55	40	48		85	33	59	55	60	54	
Spindletop	04-28-2004	71	38	54		68	37	58	52	64	50	
Spindletop	04-29-2004	75	52	64		66	40	60	55	68	55	
Spindletop	04-30-2004	71	58	64	0.03	94	68	60	58	64	60	

Summary for Spindletop for the period 4-1-2004 through 4-30-2004:

STATION	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	TOTAL PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	TOTAL EVAP
Spindletop	64	46	55	3.06	82	48	57	52	61	52	
(Deviation from normal)	-1	+1	-0	-0.82							

		AIR TEMP				RH		SOIL TEMP GRASS		SOIL TEMP BARE		
STATION	DATE	MX	MN	AV	PRECIP	MX	MN	MX	MN	MX	MN	EVAP
Spindletop	05-01-2004	78	60	69	0.31	97	59	63	60	68	61	
Spindletop	05-02-2004	61	41	51	1.03	97	73	62	56	65	55	
Spindletop	05-03-2004	58	34	46		96	41	57	53	62	51	
Spindletop	05-04-2004	62	36	49		91	49	57	52	62	51	
Spindletop	05-05-2004	76	54	65		74	41	61	55	69	56	
Spindletop	05-06-2004	80	61	70		91	43	63	58	72	60	
Spindletop	05-07-2004	82	63	72		93	52	65	61	75	62	
Spindletop	05-08-2004	83	53	68		100	41	66	61	76	64	
Spindletop	05-09-2004	83	64	74		73	39	66	63	78	66	
Spindletop	05-10-2004	83	62	72		90	47	67	63	77	67	
Spindletop	05-11-2004	81	62	72		92	53	68	64	78	68	
Spindletop	05-12-2004	83	63	73		93	49	68	64	77	68	
Spindletop	05-13-2004	78	67	72		88	59	67	65	75	69	
Spindletop	05-14-2004	79	64	72	0.22	96	56	67	66	74	69	
Spindletop	05-15-2004	66	57	62	0.65	96	91	66	64	70	67	
Spindletop	05-16-2004	74	58	66	0.02	97	70	66	64	75	65	
Spindletop	05-17-2004	82	60	71	0.01	96	57	68	64	75	66	
Spindletop	05-18-2004	80	65	72	0.13	93	64	68	66	74	68	
Spindletop	05-19-2004	78	65	72	0.41	97	79	68	66	74	69	
Spindletop	05-20-2004	83	67	75		96	66	70	67	76	70	
Spindletop	05-21-2004	83	70	76		92	69	71	69	77	71	
Spindletop	05-22-2004	83	67	75		96	63	72	69	80	71	
Spindletop	05-23-2004	83	67	75		95	51	71	69	81	72	
Spindletop	05-24-2004	83	64	74	0.18	97	58	71	69	80	73	
Spindletop	05-25-2004	83	62	72	0.36	97	67	71	69	77	71	
Spindletop	05-26-2004	72	62	67	1.89	97	91	70	68	73	70	
Spindletop	05-27-2004	82	60	71	0.73	97	68	70	67	75	68	
Spindletop	05-28-2004	78	60	69	0.27	97	52	70	67	76	69	
Spindletop	05-29-2004	77	54	66		97	58	69	66	78	67	
Spindletop	05-30-2004	70	62	66	3.30	97	84	68	67	72	70	
Spindletop	05-31-2004	77	61	69	0.28	100	43	68	67	74	69	

Summary for Spindletop for the period 5-1-2004 through 5-31-2004:

	AIR TEMP			TOTAL	RH		SOIL TEMP GRASS		SOIL TEMP BARE		TOTAL
STATION	MX	MN	AV	PRECIP	MX	MN	MX	MN	MX	MN	EVAP
Spindletop	77	60	68	9.79	94	59	67	64	74	66	
(Deviation from normal)	+2	+5	+3	+5.32							

STATION	DATE	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	EVAP
Spindletop	06-01-2004	77	56	66	0.70	97	46	67	65	73	65	
Spindletop	06-02-2004	79	58	68	0.07	95	40	68	65	74	66	
Spindletop	06-03-2004	77	56	66		94	51	68	65	77	65	
Spindletop	06-04-2004	71	55	63	0.11	97	58	67	65	72	68	
Spindletop	06-05-2004	75	49	62		99	38	67	63	75	65	
Spindletop	06-06-2004	79	57	68		85	37	67	64	75	66	
Spindletop	06-07-2004	84	58	71		92	48	69	65	77	67	
Spindletop	06-08-2004	85	65	75		93	51	74	67	82	70	
Spindletop	06-09-2004	86	68	77		99	57	74	70	80	73	
Spindletop	06-10-2004	85	66	76		100	51	76	71	82	73	
Spindletop	06-11-2004	88	72	80		100	53	76	73	83	75	
Spindletop	06-12-2004	85	66	76	0.72	100	73	75	73	79	74	
Spindletop	06-13-2004	85	63	74	0.23	100	63	76	71	81	71	
Spindletop	06-14-2004	86	71	78		100	59	78	73	83	74	
Spindletop	06-15-2004	80	71	76	0.01	100	83	77	74	81	76	
Spindletop	06-16-2004	86	70	78	0.28	100	63	79	75	82	75	
Spindletop	06-17-2004	85	71	78	0.15	100	64	79	75	83	76	
Spindletop	06-18-2004	84	70	77		100	60	80	75	83	76	
Spindletop	06-19-2004	76	61	68	0.25	100	58	78	75	81	75	
Spindletop	06-20-2004	76	55	66		97	46	78	72	81	70	
Spindletop	06-21-2004	82	59	70		88	48	77	71	83	71	
Spindletop	06-22-2004	82	68	75	0.15	100	68	76	73	81	75	
Spindletop	06-23-2004	80	64	72	0.01	100	48	78	73	82	73	
Spindletop	06-24-2004	81	63	72		100	47	76	72	82	72	
Spindletop	06-25-2004	73	65	69	0.45	100	87	74	73	77	74	
Spindletop	06-26-2004	74	60	67		100	39	75	71	80	71	
Spindletop	06-27-2004	78	55	66		100	39	76	69	83	69	
Spindletop	06-28-2004	79	58	68		100	45	76	71	82	72	
Spindletop	06-29-2004	81	61	71		100	48	77	71	84	73	
Spindletop	06-30-2004	82	61	72		100	54	77	71	84	73	

Summary for Spindletop for the period 6-1-2004 through 6-30-2004:

STATION	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	TOTAL PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	TOTAL EVAP
Spindletop	81	62	72	3.13	98	54	74	70	80	71	
(Deviation from normal)	-2	+0	-1	-0.53							

STATION	DATE	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	EVAP
Spindletop	07-01-2004	83	66	74		100	64	77	73	84	75	
Spindletop	07-02-2004	81	67	74	0.02	100	76	77	73	82	76	
Spindletop	07-03-2004	86	67	76		100	57	78	73	86	75	
Spindletop	07-04-2004	85	68	76	0.19	100	58	78	75	83	77	
Spindletop	07-05-2004	85	65	75	0.03	100	74	78	74	83	76	
Spindletop	07-06-2004	88	65	76	0.32	100	57	79	73	86	73	
Spindletop	07-07-2004	81	66	74	0.39	100	61	77	74	81	75	
Spindletop	07-08-2004	82	61	72		100	52	78	72	83	72	
Spindletop	07-09-2004	87	69	78	0.51	100	61	80	74	87	75	
Spindletop	07-10-2004	87	67	77	0.06	100	57	80	75	85	76	
Spindletop	07-11-2004	86	69	78		100	65	81	76	85	77	
Spindletop	07-12-2004	84	71	78		100	82	80	76	85	77	
Spindletop	07-13-2004	87	67	77	0.35	100	54	82	77	90	78	
Spindletop	07-14-2004	80	66	73	0.01	100	52	78	75	82	76	
Spindletop	07-15-2004	80	63	72		100	44	77	73	83	72	
Spindletop	07-16-2004	83	59	71		100	40	77	72	85	72	
Spindletop	07-17-2004	80	64	72	0.94	100	60	78	73	83	75	
Spindletop	07-18-2004	77	60	68	0.02	100	60	76	73	80	72	
Spindletop	07-19-2004	82	58	70		100	46	77	72	82	71	
Spindletop	07-20-2004	84	62	73		100	45	78	73	85	72	
Spindletop	07-21-2004	85	66	76		100	55	79	74	87	75	
Spindletop	07-22-2004	84	69	76	1.07	100	75	78	74	83	77	
Spindletop	07-23-2004	80	69	74	0.19	100	100	78	75	81	76	
Spindletop	07-24-2004	77	61	69		100	62	78	73	82	72	
Spindletop	07-25-2004	77	61	69		100	64	76	73	79	72	
Spindletop	07-26-2004	72	64	68	0.01	100	100	74	73	76	73	
Spindletop	07-27-2004	73	59	66		100	73	74	72	77	71	
Spindletop	07-28-2004	75	55	65		100	61	75	69	80	68	
Spindletop	07-29-2004	81	60	70		100	61	76	70	82	70	
Spindletop	07-30-2004	84	64	74	1.11	100	67	76	72	81	73	
Spindletop	07-31-2004	81	67	74	2.43	100	100	76	72	80	74	

Summary for Spindletop for the period 7-1-2004 through 7-31-2004:

STATION	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	TOTAL PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	TOTAL EVAP
Spindletop	82	64	73	7.65	100	64	78	73	83	74	
(Deviation from normal)	-4	-0	-2	+2.65							

STATION	DATE	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	EVAP
Spindletop	08-01-2004	84	64	74		100	57	79	73	84	73	
Spindletop	08-02-2004	85	64	74		100	50	80	74	85	73	
Spindletop	08-03-2004	87	64	76		100	52	80	74	87	74	
Spindletop	08-04-2004	84	68	76	1.48	100	79	78	75	83	77	
Spindletop	08-05-2004	77	62	70	0.39	100	45	77	73	80	73	
Spindletop	08-06-2004	72	55	64		100	44	75	71	77	68	
Spindletop	08-07-2004	77	51	64		100	36	74	68	80	66	
Spindletop	08-08-2004	80	56	68		100	37	75	69	83	69	
Spindletop	08-09-2004	80	62	71		100	56	74	71	80	71	
Spindletop	08-10-2004	83	68	76		100	60	75	71	83	72	
Spindletop	08-11-2004	74	58	66	0.03	100	51	74	71	81	71	
Spindletop	08-12-2004	68	55	62	0.07	100	58	73	70	77	71	
Spindletop	08-13-2004	66	48	57		100	59	70	67	73	66	
Spindletop	08-14-2004	74	54	64		100	41	72	67	79	66	
Spindletop	08-15-2004	77	51	64		100	38	72	66	82	67	
Spindletop	08-16-2004	80	52	66		100	36	73	66	83	68	
Spindletop	08-17-2004	79	52	66		100	41	73	67	84	69	
Spindletop	08-18-2004	84	61	72		100	56	73	68	83	71	
Spindletop	08-19-2004	88	72	80		100	48	75	71	85	75	
Spindletop	08-20-2004	78	68	73	0.11	100	76	73	72	79	75	
Spindletop	08-21-2004	77	61	69	0.04	100	49	75	71	81	72	
Spindletop	08-22-2004	83	55	69		100	40	75	68	85	70	
Spindletop	08-23-2004	83	63	73		100	47	74	70	83	73	
Spindletop	08-24-2004	82	67	74	0.06	100	91	74	71	80	74	
Spindletop	08-25-2004	85	70	78	0.22	100	86	74	72	80	74	
Spindletop	08-26-2004	80	71	76	0.20	100	100	74	72	77	74	
Spindletop	08-27-2004	87	71	79		100	75	76	72	81	73	
Spindletop	08-28-2004	90	68	79	0.31	100	57	78	74	85	75	
Spindletop	08-29-2004	80	67	74		100	90	76	74	81	75	
Spindletop	08-30-2004	74	64	69		100	100	74	73	77	74	

Summary for Spindletop for the period 8-1-2004 through 8-30-2004:

STATION	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	TOTAL PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	TOTAL EVAP
Spindletop	80	61	71	2.91	100	58	75	71	81	72	
(Deviation from normal)	-4	-1	-3	-0.89							

STATION	DATE	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	EVAP
Spindletop	09-01-2004	79	58	68		100	47	74	69	83	71	
Spindletop	09-02-2004	81	62	72	0.04	100	68	74	70	81	72	
Spindletop	09-03-2004	79	68	74	0.22	100	100	74	71	78	74	
Spindletop	09-04-2004	86	67	76		100	54	77	72	82	73	
Spindletop	09-05-2004	85	65	75		100	50	77	72	84	73	
Spindletop	09-06-2004	85	62	74		100	50	77	72	86	73	
Spindletop	09-07-2004	79	67	73	0.02	100	100	75	73	79	75	
Spindletop	09-08-2004	70	64	67	0.49	100	100	73	70	76	71	
Spindletop	09-09-2004	73	61	67		100	100	71	69	74	70	
Spindletop	09-10-2004	77	53	65		100	53	72	67	77	67	
Spindletop	09-11-2004	82	58	70	0.03	100	53	74	67	79	68	
Spindletop	09-12-2004	81	65	73	0.22	100	62	75	70	79	72	
Spindletop	09-13-2004	80	63	72		100	66	74	71	78	72	
Spindletop	09-14-2004	82	62	72		100	49	74	70	78	70	
Spindletop	09-15-2004	83	62	72		100	53	74	70	79	70	
Spindletop	09-16-2004	77	67	72		100	100	73	71	76	73	
Spindletop	09-17-2004	67	53	60	1.59	100	100	71	68	73	67	
Spindletop	09-18-2004	73	48	60		100	44	69	65	74	63	
Spindletop	09-19-2004	71	49	60		100	37	68	64	73	63	
Spindletop	09-20-2004	76	48	62		100	34	68	63	74	62	
Spindletop	09-21-2004	80	48	64		100	39	69	63	75	63	
Spindletop	09-22-2004	82	54	68		100	43	70	64	78	66	
Spindletop	09-23-2004	84	57	70		100	46	71	66	79	68	
Spindletop	09-24-2004	83	59	71		100	42	71	67	78	69	
Spindletop	09-25-2004	76	58	67		100	46	70	67	75	69	
Spindletop	09-26-2004	74	55	64		100	52	69	66	77	67	
Spindletop	09-27-2004	76	54	65		100	65	69	65	75	67	
Spindletop	09-28-2004	76	59	68		100	36	69	67	77	69	
Spindletop	09-29-2004	64	50	57		100	67	67	65	72	67	
Spindletop	09-30-2004	69	44	56		100	57	66	62	71	63	

Summary for Spindletop for the period 9-1-2004 through 9-30-2004:

STATION	AIR TEMP MX	AIR TEMP MN	AIR TEMP AV	TOTAL PRECIP	RH MX	RH MN	SOIL TEMP GRASS MX	SOIL TEMP GRASS MN	SOIL TEMP BARE MX	SOIL TEMP BARE MN	TOTAL EVAP
Spindletop	78	58	68	2.61	100	60	72	68	77	69	
(Deviation from normal)	+0	+2	+1	-0.59							

Evaluation of Surfactant Types in Combination with 2,4-D for Broadleaf Weed Control

Introduction

Surfactants are a type of additive that is used in herbicide mixtures to increase herbicide efficacy by increasing herbicide absorption. Surfactants can be classified as a type of adjuvant and are technically defined as “a compound that improves the emulsifying, dispersing, spreading, wetting or other surface-modifying properties of liquids” (Bohmont 1990). Surfactants produce physical changes at the surface of liquids and these changes take place at the interface between the two liquids (Anderson 1996). These compounds enhance the emulsifying, dispersing, wetting, spreading, sticking, penetrating, and other surface-modifying properties of liquids.

There are four general classes of surfactants based on their ionization in water: anionic, cationic, nonionic, and amphoteric (Anderson 1996). All surfactants share a common characteristic of a water soluble group of molecules attached to a oil-soluble chain. Anionic and cationic get their names from their ability to ionize in water and use their anions or cations to produce their surface-active properties. Anionic surfactants have the ability to have their ions react with other ions including the herbicide itself which may decrease the solutions efficacy. Cationic surfactants are derived from ammonia and are not readily used in herbicide solutions. They are phytotoxic, precipitate in hard water, and are poor detergents making them unfavorable herbicide solution additives. Amphoteric surfactants act as either anionic or cationic surfactants, depending on the pH levels of the solution being used.

Nonionic surfactants came into widespread use in the 1960’s and are probably the most common type of surfactant used in herbicide solutions (Anderson 1996). These types of surfactants do not ionize in water and are therefore not affected by hard water. They also maintain their properties in acidic solutions further adding to their versatility. The most favorable characteristic of nonionic surfactants is their ability to act as emulsifiers to create stable formulations. This characteristic adds to their widespread use.

There are other herbicide solution adjuvants that are commonly used in place of surfactants to achieve the same results. Crop oils, such as methylated seed oil, are recommended as surfactants on some herbicide labels. These products usually contain 83-85 % oil and 15-17 % emulsifier to enable the solution to be mixed in water (Anderson 1996). Liquid nitrogen fertilizers, such as urea-ammonium nitrate and ammonium sulfate, can be added to herbicide mixtures to increase the phytotoxicity of foliar applied herbicides (Anderson 1996). Though not surfactants per se these products can be mentioned in herbicide labels as an additive to the spray solution or as a carrier.

There is a wide array of nonionic surfactants and other spray solution additives available to vegetation managers with different ingredients and benefits. It is unclear if there is a difference in these compounds in aiding herbicide efficacy. A study was designed to evaluate different nonionic surfactants and additives in combination with a commonly used herbicide, 2,4-D, for broadleaf weed control.

Methods and Materials

Two trials were installed in August 2004. The goal of the trials was to compare the efficacy of 2,4-D to provide broadleaf weed control using different types of surfactants or other adjuvants (Table 1). The first study was located in a road construction waste storage lot in the median of the Bluegrass Parkway near Bardstown, Kentucky. Predominant weed cover included white heath aster, marestail, and common lambsquarters. The second study was located at the Spindletop Research Station in Lexington, KY. Predominant weed cover included white and red clover, Canada thistle, white heath aster, dandelion, and curly dock. Both studies were a randomized complete block design with three replications (blocks being replications) and used the same treatment list (Table 2). Hi-Dep IVM was the 2,4-D formulation used in both studies due to it's unique 2,4-D formulation and inclusiveness of all species occurring at both sites in the weeds controlled section of the label. Plots were 5' X 20' and treatments were applied with a CO_2 powered sprayer equipped with TeeJet 8004 flat fan tips. Applications were made at 20 GPA.

Table 1: Ingredient list for adjuvants tested

Adjuvant Common Name	Ingredient(s)
Activator 90	90 % alkyl polyoxyethylene ether & free fatty acids
SurfAc 820	80 % alkyl and alkylaryl polyoxyethylene glycol
NuFilm	96 % poly-l-p Menthene
Cide-Kick	100 % d'limonene and related isomers plus selected emulsifiers
GlyAd Ultra	34 % ammonium sulfate + 66 % adjuvants
MSO Concentrate	100 % methylated seed oil and emulsifying surfactants

Table 2: Treatment list for adjuvant comparison study

Treatment	Products	Rate
1	HiDep + Activator 90	64 fl oz + 0.25 % v/v
2	HiDep + SurfAc 820	64 fl oz + 0.25 % v/v
3	HiDep + NuFilm	64 fl oz + 0.25 % v/v
4	HiDep + Cide-Kick	64 fl oz + 1 % v/v
5	HiDep + GlyAd Ultra	64 fl oz + 0.5 % v/v
6	HiDep + MSO Concentrate	64 fl oz + 0.5 % v/v
7	HiDep	64 fl oz
8	Untreated Control	

Data were collected at 40 DAT for the Bardstown trial and 37 and 71 DAT for the Spindletop trial. Visual estimation of percent control of broadleaf weeds was determined and analyzed using ARM software. Untreated control data were omitted from analysis to reduce variance and treatment means were compared using Fisher's LSD test at $p = 0.05$.

Results

Bardstown

There was no statistically significant difference between any of the treatments 40 DAT (Table 3). There were higher levels of control with treatments containing an adjuvant than the HiDep alone treatment.

Spindletop

Unlike the Bardstown trial, a significant treatment difference existed between the HiDep + Cide-Kick treatment and the Hi-Dep + GlyAd Ultra treatment at 37 DAT (Table 4). There were no significant treatment differences between all other treatments at the same time interval. Control decreased for all treatments by 71 DAT. There was a significant difference between both the HiDep + MSO Concentrate treatment and HiDep alone treatment and all other treatments.

Data presented here simply compares adjuvants for general broadleaf weed control. Future work will include the concentration on one or two difficult to control species and one or two easily controlled species with 2,4-D and the same adjuvants tested here. Rate titrations of adjuvants will also be evaluated.

Table 3: Summary results for Bardstown adjuvant trial

Trt No.	Type	Treatment Name	Rate	Rate Unit	% Control 40 DAT	
1	HERB	Hi Dep	64	fl oz/a	77	a
	ADJ	NIS	0.25	% v/v		
2	HERB	Hi Dep	64	fl oz/a	53	a
	ADJ	80/20	0.25	% v/v		
3	HERB	Hi Dep	64	fl oz/a	70	a
	ADJ	Nu Film	0.25	% v/v		
4	HERB	Hi Dep	64	fl oz/a	73	a
	ADJ	Cide Kick	1	% v/v		
5	HERB	Hi Dep	64	fl oz/a	50	a
	ADJ	AMS	0.5	% v/v		
6	HERB	Hi Dep	64	fl oz/a	57	a
	ADJ	MSO	0.5	% v/v		
7	HERB	Hi Dep	64	fl oz/a	47	a
8	CHK	Untreated Check			0	

Note: Treatment means followed by the same letter are not significantly different using Fisher's LSD at $p = 0.05$.

Table 4: Summary results for the Spindletop adjuvant trial

Trt No.	Type	Treatment Name	Rate	Rate Unit	Percent Control 37 DAT		71 DAT	
1	HERB	Hi Dep	64	fl oz/a	68	ab	57	ab
	ADJ	NIS	0.25	% v/v				
2	HERB	Hi Dep	64	fl oz/a	68	ab	63	a
	ADJ	80/20	0.25	% v/v				
3	HERB	Hi Dep	64	fl oz/a	73	ab	53	ab
	ADJ	Nu Film	0.25	% v/v				
4	HERB	Hi Dep	64	fl oz/a	63	b	50	ab
	ADJ	Cide Kick	1	% v/v				
5	HERB	Hi Dep	64	fl oz/a	78	a	50	ab
	ADJ	AMS	0.5	% v/v				
6	HERB	Hi Dep	64	fl oz/a	68	ab	45	b
	ADJ	MSO	0.5	% v/v				
7	HERB	Hi Dep	64	fl oz/a	70	ab	42	b
8	CHK	Untreated Check			0		0	

Note: Treatment means followed by the same letter are not significantly different using Fisher's LSD at p = 0.05.

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Evaluation of 2,4-D Formulations for Broadleaf Weed Control

A trial was installed to compare different commonly available 2,4-D formulations for broadleaf weed control. This study was a by-product of the adjuvant comparison study as investigators at UK questioned if results of the adjuvant study would have been different if a different formulation of 2,4-D was used. Liquid formulations of 2,4-D were compared for efficacy.

The trial was a randomized complete block design with three replications (blocks being replicates). The study was located at the Spindletop Research Station next to the adjuvant comparison study. Plots were 5' X 20' and treatments were applied using a CO_2 powered sprayer equipped with TeeJet 8004 flat fan tips. Four chemical treatments were applied (Table 5) at 20 GPA. All treatments were made at 64 fl oz / ac and included a non-ionic surfactant (Activator 90) at 0.25 % v/v.

Table 5: Treatment list for 2,4-D comparison

Treatment	Trade Name	Formulation	Concentration
1	Formula 40	Triisopropanolamine salt (34.05%) and dimethylamine salt (21.97%) of 2,4-dichlorophenoxyacetic acid	3.67 lb acid equivalent / gal
2	HiDep IVM	Dimethylamine salt of 2,4-dichlorophenoxyacetic acid (33.2 %) and diethanolamine salt of 2,4-dichlorophenoxyamine acid (16.3 %)	3.8 lb acid equivalent / gal
3	Weedar 64	Dimethylamine salt of 2,4-dichlorophenoxyacetic acid (46.8%)	3.8 lb acid equivalent / gal
4	Butyrac 200	Dimethylamine salt of 4-(2,4-dichlorophenoxy) butyric acid (25.9 %)	2.0 lb acid equivalent / gal
5	Untreated control		

The study site had the same weed complex as the Spindletop adjuvant study. Predominant weed populations at the time of application included red and white clover, Canada thistle, white heath aster, dandelion, and curly dock. Data collected included visual estimation of percent control of broadleaf weeds at 37 and 71 DAT. Data were analyzed in ARM software using Fisher's LSD test at $p = 0.05$ to compare treatment means. Untreated control plots were removed from analysis to reduce variance.

Results

All treatments except Butyrac 200 provided control of broadleaf weeds greater than 60 % control from 37 DAT (Table 6). There was significant difference between the first three treatments. The Weedar 64 treatment decreased as the trial continued on to 71 DAT while the Butyrac 200 treatment increased in control 71 DAT. The Formula 40 and HiDep treatments decreased slightly as the trial progressed from 37 to 71 DAT. There was no significant difference in control levels between the Formula 40, HiDep, and Butyrac 200 treatments at 71 DAT.

The results for HiDep are consistent with those presented in the adjuvant trial. The ability for Butyrac 200 to provide the same level of control that the Formula 40 and HiDep treatments indicate that a lower rate of the latter two compounds may be as effective since Butyrac 200 is almost ½ as concentrated as Formula 40 and HiDep.

Future work will include the addition of dry 2,4-D to the trial. Lower rate titrations will also be evaluated in an attempt to quantify if a certain formulation of 2,4-D may provide satisfactory control at a lower cost. As with the adjuvant trial, future work will also be species specific in identifying one or two difficult to control species and one or two easily controlled species and collecting efficacy data.

Table 6: Summary results for 2,4-D comparison trial

Trt No.	Type	Treatment Name	Rate	Rate Unit	Percent Control 37 DAT		71 DAT	
1	HERB	Formula 40	64	fl oz/a	70	a	57	a
	ADJ	NIS	0.25	% v/v				
2	HERB	HiDep	64	fl oz/a	65	a	57	a
	ADJ	NIS	0.25	% v/v				
3	HERB	Weedar 64	64	fl oz/a	67	a	38	b
	ADJ	NIS	0.25	% v/v				
4	HERB	Butyrac 200	64	fl oz/a	45	b	62	a
	ADJ	NIS	0.25	% v/v				
5	CHK	Untreated Check			0		0	

Note: Treatment means followed by the same letter are not significantly different using Fisher's LSD test at p = 0.05

Control of Japanese Knotweed (*Polygonum cuspidatum*)

Introduction

Japanese knotweed is a federally listed invasive perennial native to Asia (NAL 2004). This herbaceous plant (sometime referred to as semi woody) was introduced into England in the early 1800s and was subsequently introduced into North America as an ornamental (Figueroa 1989, Uva et al 1997). This species has now spread across the Pacific Northwest, Midwest, and eastern United States (USDA NRCS 2004).

Japanese knotweed is problematic for land managers due to its aggressive nature and reproduction capabilities. The plant can establish itself on a wide array of site conditions but can establish and grow exceedingly well in areas of partial to high sunlight and moist well-drained soils such as roadsides, utility rights-of-way, and river and stream banks (McCormick 2000, Uva et all 1997). Stems are hollow and jointed, much like bamboo, and can reach heights up to 2 meters (approximately 10 feet). Plants form either male and female white flowers (dioecious) in late summer or form three sided seed like fruit. There is some confusion as whether or not seeds produced from plants naturalized in the United States are viable. Pure strains of Japanese, giant, or Himalayan knotweed are thought not to produce viable seed while hybrid varieties can produce viable seeds (Soll 2004). Japanese knotweed can also reproduce vegetatively from thick rhizomes that can reach 40 to 60 feet in length and annual growth of 8 feet is not uncommon (McCormick 2000). This vegetative reproduction can lead to the formation of dense colonies of Japanese knotweed that can out compete native species. Above ground portions usually die with a hard frost while the below ground rhizomes remain viable for growth the following year.

Individual plant parts created from mechanical mowing can remain viable and lead to the spread of this plant. Due to its habitat usually occurring near flowing water, flooding disturbances can transport plant parts to be deposited in uncolonized areas further compounding the problem. Homeowner mowing clippings and vehicle transport of plant parts have also lead to the spread of Japanese knotweed (Figueroa 1989).

Control and Eradication

Control and eradication of this species in unwanted areas is difficult due to its above stated vegetative reproduction capabilities. Mechanical mowing only exponentially compounds the problem while removal of the plant can be cost prohibitive on large scales. Removal and destruction of plant parts is usually ineffective due to dense rhizomial mats formed and the ability for an individual plant part that is missed to resprout. Other mechanical methods such as covering mowed infestations with black plastic to limit sunlight have been shown to be ineffective as well (McCormick 2000).

Control recommendations are commonly made by conservation groups such as the NRCS, The Nature Conservancy, and state conservation agencies. When examining these recommendations there is one common caveat. A single chemical treatment will be ineffective in controlling infestations. One of the most common recommendations to chemically control Japanese knotweed is a foliar application of glyphosate in the spring when colonies first begin to actively grow and another application in the late summer /

early fall while the plant in translocating reserves from the leaves to the root systems. Recommended application rates range from 1.78 lb a.i. / ac (Seiger 1991) to 4 lb a.i. / ac (Rhoads and Block 2002). The recommendations reviewed here failed to recommend a carrier volume (i.e. total solution applied per acre).

Chemical control options have been researched extensively in the past and have included the use of glyphosate, dicamba, 2,4-D, picloram, triclopyr, and fosamine (Figueroa 1989). In a study comparing clopyralid, imazapyr, dicamba, 2,4-D, and glyphosate, Figueroa (1989) showed effective reduction of Japanese knotweed density using imazapyr at 0.6 kg a.i. / ha (approximately 0.5 lb a.i. / ac) when applied in mid-June as a foliar application. Research conducted at the Penn State Roadside Vegetation Management Research project showed that a single application of glyphosate at 4 qt / ac in 200 gallons / ac of water applied in October provided 97 % reduction of Japanese knotweed when evaluated the following June (Kuhns et al 2002).

Research performed at Virginia Tech has shown promise in identifying effective chemical control options. A study initiated in 2003 to compare glyphosate, imazapyr, metsulfuron, and fosamine applied as a foliar spray at 50 GPA. Glyphosate (formulated as RoundUp Pro) applied at a 1 % v/v solution applied in late August as a foliar application provided excellent control (> 90%) at 1 YAT (Hipkins and Witt 2004). The same study showed that a fosamine (formulated as Krenite S) + imazapyr (formulated as Arsenal) at a 1 % v/v + 0.125 % v/v solution provided good control levels (81.7 %) 1 YAT while increasing the fosamine rate to 2 % v/v increased control to 88.3 % 1 YAT. Fosamine alone at 2 % v/v provided low levels of control 1 YAT (30 %) as did tank mixed of fosamine and metsulfuron (1 % v/v + 2 oz / 100 gal and 2 % v/v + 2 oz per 100 gal) provided similarly unsatisfactory results 1 YAT (< 5 % and 30 % control, respectively).

A study was initiated in June of 2004 to compare fosamine, imazapyr, glyphosate, triclopyr, and dicamba to control of Japanese knotweed in eastern Kentucky. The site was a roadside shoulder with mixed hardwoods as a rear boundary for a majority of the area and a kudzu infestation as the rear boundary for the remaining area. Treatments were applied at 50 GPA using a boomless tip mounted on an ATV equipped with a CO_2 powered sprayer to provide a foliar roadside application. Unfortunately, the kudzu infestation overtook the third replication and two plots in the second replication in the study thus making any data collected insufficient. Though not analyzed statistically, initial observations showed that the Overdrive (a.i. diflufenzopyr + dicamba) plus Garlon 3A treatment (4 oz + 64 fl oz, respectively) reduced cover of Japanese knotweed from 100% to less than 25 % in two of the three replications at approximately 4 MAT. Glyphosate (formulated as RoundUp Pro and Glyphomate 41) were beginning to decrease cover to less than 40 % at the same time interval. It is unclear as to the effect that the imazapyr + fosamine treatments would have had since imazapyr is slow to show symptomology on certain species and fosamine does not show effects until the following growing season (inhibition of leaf out). It must be reiterated that these results are simply **observations and not analyzed statistically and should not be cited**. This study will be installed again during the 2005 season to evaluate the efficacy of these treatments.

Summary

Mechanical removal of Japanese knotweed could be effective in extremely small infestations where one could consistently and repeatedly observe the site and remove all plant parts (including rhizomes). Mowing Japanese knotweed provides short term solution and should be avoided as this may spread the plant to other area compounding the problem.

Chemical control of Japanese knotweed colonies may prove to be more cost effective in the long term if used accurately. All chemical treatments should be applied at a high carrier rate (50 GPA or higher) to ensure sufficient coverage of foliage. Site characteristics (location of desirable vegetation, proximity to water, etc) should also be considered when choosing herbicides. High rates of glyphosate (1 % or greater v/v or 1 gallon per acre or greater) seem to be effective when applied in the spring and again in the fall or once in the fall and retreating the following spring. Glyphosate is non-selective and will injure or kill desirable species if accidentally treated. However, there are aquatic labeled glyphosates on the market and can be used in close proximity to bodies of water.

The fosamine plus imazapyr treatments used by Hipkins and Witt (2004) showed effective reduction of cover when applied late season. This mixture may be more suitable where desirable species are present that would otherwise be injured by glyphosate. It should be stated that all treatments researched and mentioned here will undoubtedly require at least annual, if not semi-annual, applications to completely remove active Japanese knotweed infestations and any regrowth that occurs.

Future research to be conducted at the University of Kentucky includes evaluation of the fosamine + imazapyr treatments, diflufenzopyr + dicamba + triclopyr treatments, and glyphosate. Metsulfuron will also be evaluated as a tank mix partner for the above mentioned combinations to provide a component for kudzu control will evaluating any antagonism it may have in Japanese knotweed control.

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Chemical Control of Kudzu (*Pueraria lobata)*

Introduction

Kudzu is an invasive vine native to Japan and China. This species has become naturalized across the southeastern United States and is a severe problem for land managers due to its rapid growth rate and prolific seed production. Control options have been researched heavily in the past 50 years and have included biological control (e.g. goats and seed weevils), chemical control, and structural modification to prevent climbing of the vine.

Although it is unclear exactly how many of acres of Kentucky are infested with Kudzu, there are an estimated 12 million acres in the southern United States. The problem in Kentucky is not as severe as other southern states such as Alabama and Georgia, but it is clear that left unchecked, the problem could be just as great in the near future. To make matters worse, it has been realized that kudzu is a host to soybean rust that has wreaked havoc in South America. It is estimated that this rust will spread in the United States within five years further strengthening the need for kudzu control here in Kentucky.

There are many chemical control options available to deal with kudzu infestations. James Miller (2003) has recommended the following from July through October for successive years on regrowth for complete control: Tordon 101M @ 3 % v/v (a.i. picloram), Torkon K @ 2 % v/v (a.i. picloram), Escort @ 3-4 oz / ac (a.i. metsulfuron), and Transline @ 0.5 % v/v (a.i. clopyralid). Transline controls a narrow spectrum of species and is desirable when nontarget species are present.

The purpose of this trial was to determine efficacy of several compounds to could be used to provide an initial significant burndown of a kudzu infestation. Since eradication of a kudzu infestation will undoubtedly require a multiseasonal approach, an effective initial burndown of the entire area will allow the manager to better understand the scope of the infestation and landscape he or she is dealing with. This may allow for a more site specific follow-up treatment that may be more effective in eradicating the species in a timely and cost effective manner.

Methods and Materials

The study site was located at the KenLake State Park in Marshall County, Kentucky. The area infested was alongside a paved road with the topography sloping downward on either side of the road. A randomized complete block design was installed with three replications (blocks being replicates) with plots being 15’ X 30’. Eight chemical treatments and one untreated control (Table 1) were applied on June 29th, 2004 using an ATV equipped with a CO_2 sprayer. A TeeJet boomless tip (size 25) was used to provide a roadside application at 50 GPA. All treatments except for the RoundUp Pro treatment included a nonionic surfactant at 0.5% v/v. All plots had 100% cover of kudzu at application. Evaluations of the plots were conducted at 37 and 82 DAT where visual estimation of percent control (0 – 100 %) was determined. Data were analyzed using ARM software and untreated control measurements were removed from analysis to reduce error variance (all untreated plots had 0 % control). Data failed to pass Bartlett’s test for homogeneity of variance and was transformed using the arcsine transformation to reduce this variance. Results presented here show the untransformed treatment means and transformed data treatment means comparisons. Treatment means were compared using Fisher's LSD at $p = 0.05$.

Table 1: Treatment list for kudzu trial in KenLake State Park

Treatment	Compounds	Active Ingredients	Rate per acre	Estimated cost per acre
1	Grazon P & D	Picloram + 2,4-D	1 gal	$36.00
2	Escort	Metsulfuron	4 oz	$75.00
3	Banvel + 2,4-D	Dicamba + 2,4-D	96 fl oz	$22.50
4	Stinger	Clopyralid	21 fl oz	$52.00
5	Garlon 4	Triclopyr	2 gal	$175.00
6	Round Up Pro + Arsenal	Glyphosate + imazapyr	1 gal + 16 fl oz	$77.00
7	BK 800	Isoctyl ester of 2,4-D + ethylhexyl ester of 2,4-D + dicamba	2 gal	$98.00
8	Confront	Triclopyr + clopyralid	32 fl oz	$35.00
9	Untreated			

Non-crop labeled products were not available for some of the treatments. As such, Grazon P & D was used in place of Tordon 101M, Stinger was used in place of Transline, and Confront was used in place of Redeem R & P. Costs per acre are included in Table 1 and are **estimated** based on retail costs of the non-crop products.

Results

Grazon P & D, Escort, and Garlon 4 treatments resulted in percent control ratings greater than 90% by 82 DAT (Table 2). The Escort, Banvel, Garlon 4, BK 800, and Confront treatments provided excellent initial burndown at 37 DAT; however, the Banvel, BK 800, and Confront treatments regressed in percent control as the trial continued. Stinger never provided control greater than 68 % through the study. The RoundUp + Arsenal treatment provided satisfactory control at 37 DAT but decreased severely as the trial progressed.

Although the Grazon P & D, Escort, and Garlon 4 treatments produced similar efficacy results, the Escort treatment is recommended for initial burndown for cost considerations (as compared to Garlon 4) and environmental conditions (as compared to Grazon P & D). It is unclear why the clopyralid (Stinger) treatments resulted in low percent control values as clopyralid has been shown to be effective in reducing kudu cover to 3% by 8 WAT (Rader and Harrington 1998). Follow up treatments for regrowth may include Garlon 4 at a 2 % v/v solution for spot spraying or possibly a clopyralid (Transline) solution at 0.5 % v/v.

This study will be re-evaluated in the spring of 2005 to determine residual efficacy of the treatments and possibly retreatment of the plots with follow-up spot treatments.

Table 2: Summary results for Kenlake kudzu trial

Trt No.	Type	Treatment Name	Rate	Rate Unit	Visual Percent Control 37 DAT		82 DAT	
1	HERB	Grazon P & D	1	gal/a	86	a	95	ab
	ADJ	NIS	0.5	% v/v				
2	HERB	Escort	4	oz/a	98	a	96	ab
	ADJ	NIS	0.5	% v/v				
3	HERB	Banvel + 2,4-D	96	fl oz/a	93	a	78	ab
	ADJ	NIS	0.5	% v/v				
4	HERB	Stinger	21	fl oz/a	67	b	68	bc
	ADJ	NIS	0.5	% v/v				
5	HERB	Garlon EC	2	gal/a	98	a	99	a
	ADJ	NIS	0.5	% v/v				
6	HERB	Roundup Pro	1	gal/a	85	ab	37	c
	HERB	Arsenal 2	16	fl oz/a				
7	HERB	BK 800	2	gal/a	96	a	72	abc
	ADJ	NIS	0.5	% v/v				
8	HERB	Confront	32	fl oz/a	93	a	73	abc
	ADJ	NIS	0.5	% v/v				
9	CHK	Untreated Check			0		0	

Note: Treatment means followed by the same letter at the same time interval are not statistically significantly different using Fisher's LSD at p = 0.05.

Literature Cited

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Control of Johnsongrass (*Sorghum halepense*) in Tall fescue (*Festuca arundinacea*) Stands

Introduction

Johnsongrass is a nonnative invasive species introduced as a forage crop from the Mediterranean region (Miller and Miller 1999). This perennial species has become naturalized and is found in 47 of the 50 United States (Alaska, Minnesota, and Maine being the exceptions) (USDA 2004). Johnsongrass has become problematic along roadsides in Kentucky due to its aggressive and prolific nature and rapid growth habit. Johnsongrass reproduces by seed and by rhizomes which adds to its invasive nature. This plant can cause line of sight issues, maintenance concerns along guardrails, and unsightly rights-of-way. The past management regime for Johnsongrass for the Kentucky Transportation Cabinet has been chemical treating infestations with an ACCase type herbicide (e.g. Fusion®, a.i. fluazifop + fenoxaprop) along the guardrails and vehicle recovery areas and mowing operations for areas outside these areas. Unfortunately, there have been reported cases of Johnsongrass developing resistance to the ACCase type herbicides in agricultural settings in Kentucky (Obermeier et al 1998). Graminicide resistant Johnsongrass has also been reported in Mississippi, Tennessee, Virginia, Louisiana, and Texas (weedscience.org 2003). Although no cases have been officially documented on KTC property, the potential for herbicide resistance exists to make this invasive species more of a problem. Evaluation of herbicide chemistries with modes of action different to that of graminicides (ACCase inhibitors) needs to be evaluated for efficacy to provide the KTC a cost effective alternative to Fusion for an annual application rotation.

Outrider® (a.i. sulfosulfuron) was shown to be an effective control option for Johnsongrass. Outrider has a different mode of action (ALS inhibitor) than that of graminicides and may prove to be a feasible control option and\or rotation partner with current control strategies. The goal of the trials presented here was to evaluate the efficacy of Envoy (a.i. clethodim), Fusion, and Outrider in controlling Johnsongrass and the effect that the compounds have on tall fescue stands.

General Methods and Materials

Several studies were initiated in the 2004 growing season. One study was located in western Kentucky and three studies were located in central Kentucky. All studies were similar in that each contained at least one clethodim (Envoy) treatment, one fluazifop + fenoxaprop (Fusion) treatment, and one sulfosulfuron (Outrider) treatment. All studies were randomized complete block designs with three replications of each treatment and had plot sizes 5' X 20'. The western Kentucky (Central City) study was treated at 25 GPA while the three central Kentucky studies (Spindletop, Main Chance, I 75) were treated at 20 GPA. All studies were treated with a CO_2 powered hip sprayer using two TeeJet 8004 flat fan tips. Data collected included visual percent control (0 – 100 %) and visual estimation of fescue damage using a 0 – 9 color index scale (0 = dead, 9 = green). Data sets were analyzed using Agricultural Research Manager (ARM) software and treatment comparisons were made using Fisher's LSD test at the p = 0.05 level for significance. Percent control data of the untreated check treatments were removed from analysis to reduce variation (all had 0 % control) while color measurements of untreated check plots were retained. Data were transformed using the arcsine transformation when data sets did not meet Bartlett's test for homogeneity of variance. Results presented here show the untransformed treatment means and the transformed data mean comparisons when transformations were necessary. Results are presented for each separate study.

Site Specific Methods and Results

Central City

The Central City study utilized 8 chemical treatments and 1 untreated control treatment (Table 1). Estimated cost per acre for each treatment is included **for comparison purposes only**.

Table 1: Treatment list for Central City Johnsongrass trial

Treatment	Compounds	Rate per acre	Cost per acre
1	Envoy + COC	13 fl oz + 1% v/v	$12.00
2	Envoy + COC	15 fl oz + 1% v/v	$14.00
3	Envoy + COC	17 fl oz + 1% v/v	$15.00
4	Outrider + NIS	0.5 oz + 0.5% v/v	$5.00
5	Outrider + NIS	0.75 oz + 0.5% v/v	$8.00
6	Outrider + NIS	1 oz + 0.5% v/v	$10.00
7	Fusion + NIS	7 fl oz + 0.25% v/v	$6.00
8	Fusion + NIS	9 fl oz + 0.25% v/v	$8.00
9	MSMA	32 fl oz	$4.00
10	Untreated		

The trial was installed on June 17th, 2004. Plots were rated 28, 62, and 96 days after treatment (DAT). All Envoy treatments and Fusion treatments had > 90% control of Johnsongrass 28 DAT (Table 2). All Envoy treatments were able to maintain a relatively high degree of control at 96 DAT. Fusion treatments; however, appeared to decrease in their overall effectiveness by 96 DAT as control responses were below 90 %. A rate response was observed for the Outrider treatments as there was an increase in percent control as rates increased from 0.5 oz / ac to 1 oz / ac. Control of Johnsongrass ranged from 63 – 82 % for rates of Outrider tested at 28 DAT and increased to 89 – 98 % control by 96 DAT. Outrider at 1 oz / ac provided the best amount of Johnsongrass control by 96 DAT at 98 % control. The MSMA treatments did provide comparable Johnsongrass control.

All Envoy and Outrider treatments realized a negative effect on fescue color Table 2). This may have been influenced by the environmental conditions as western Kentucky experienced a relatively dry summer in 2004. Fusion treatments appeared to have allowed the fescue to effectively rebound from the initial damage as did the MSMA treatment.

Notes: The following was observed at the last measurement interval (96 DAT). These observations were not analyzed statistically.

- Envoy appeared to control yellow foxtail while Outrider did not.
- Yellow foxtail seems rate sensitive to Fusion as foxtail was present in the 7 oz / ac plots and absent in the 9 oz / ac plots.
- Broomsedge appears to be tolerant to Outrider while rate sensitive to Envoy. Envoy never controlled broomsedge but the high rate (17 oz / ac) appeared to have a stunting effect.

Table 2: Summary of Central City Johnsongrass Trial

Trt		Treatment		Rate	Percent control						Color ratings					
No.	Type	Name	Rate	Unit	28 DAT		62 DAT		96 DAT		28 DAT		62 DAT		96 DAT	
1	HERB	Envoy	13	fl oz/a	98	a	87	a	90	ab	4	cde	2	de	2	de
	ADJ	COC	1	% v/v												
2	HERB	Envoy	15	fl oz/a	93	abc	80	a	96	ab	3	de	2	de	2	de
	ADJ	COC	1	% v/v												
3	HERB	Envoy	17	fl oz/a	98	a	87	a	94	ab	3	e	2	de	1	e
	ADJ	COC	1	% v/v												
4	HERB	Outrider	0.5	oz/a	63	e	72	a	89	ab	5	bc	3	cd	3	cd
	ADJ	NIS	0.5	% v/v												
5	HERB	Outrider	0.75	oz/a	75	de	80	a	96	ab	4	cde	1	e	3	c
	ADJ	NIS	0.5	% v/v												
6	HERB	Outrider	1	oz/a	82	cde	92	a	98	a	5	bcd	1	e	3	c
	ADJ	NIS	0.5	% v/v												
7	HERB	Fusion	7	fl oz/a	96	ab	70	a	64	b	4	bcde	5	bc	6	b
	ADJ	NIS	0.25	% v/v												
8	HERB	Fusion	9	fl oz/a	93	abc	88	a	80	ab	4	bcde	7	ab	7	ab
	ADJ	NIS	0.25	% v/v												
9	HERB	MSMA	32	fl oz/a	82	bcd	70	a	89	ab	6	b	4	c	8	a
10	CHK	Untreated Check			0		0		0		9	a	8	a	8	a

Note: Values followed by the same letter at a given time interval are not statistically significantly different at the p = 0.05 level using Fishers LSD test.

Spindletop

The Spindletop study utilized 11 chemical treatments and 1 untreated control (Table 3). Estimated cost per acre for each treatment is included **for comparison purposes only**. The Spindletop trial included an Outrider spot treatment (treatment 7). The trial was installed on August 16th, 2004. Plots were rated 31 and 67 DAT for percent control of Johnsongrass and turf injury. A 90 DAT was not taken due to the potential of frost injury confounding the data. All Envoy treatments showed similar control results here as in the Central City trial. Treatments exhibited a quick control response at 31 DAT and then decreased slightly at 67 DAT yet still had control greater then 90 % (Table 4). The Outrider treatments maintained percent control greater then 90 % throughout the study and began to exhibit the same rate response as at Central City at 67 DAT. The Outrider spot treatment also exhibited control greater than 90 %. This treatment is **extremely** dependent on accurate identification of Johnsongrass. Fusion treatments exhibited excellent control as well throughout the trial with results similar to other treatments here and Fusion treatments at Central City. MSMA appears to have an antagonistic effect on Outrider when the two are mixed as control responses with this treatment were significantly lower than that of Outrider alone at 0.5 oz / ac throughout the trial while statistically similar to that of the MSMA alone treatment.

Table 3: Treatment list for Spindletop Johnsongrass trial

Treatment	Compounds	Rate per acre	Cost per acre
1	Envoy + COC	13 oz + 1% v/v	$12.00
2	Envoy + COC	15 oz + 1% v/v	$14.00
3	Envoy + COC	17 oz + 1% v/v	$15.00
4	Outrider + NIS	0.5 oz + 0.5% v/v	$5.00
5	Outrider + NIS	0.75 oz + 0.5% v/v	$8.00
6	Outrider + NIS	1 oz + 0.5% v/v	$9.10
7	Outrider + NIS	1 oz / 100 gl + 0.5 % v/v	$12.00 per 100 gl
8	Fusion + NIS	7 oz + 0.25% v/v	$6.00
9	Fusion + NIS	9 oz + 0.25% v/v	$8.00
10	Outrider + MSMA	0.5 oz + 32 oz	$8.00
11	MSMA	32 oz	$4.00
12	Untreated		

Table 4: Summary of Spindletop Johnsongrass Trial

Trt		Treatment		Rate	Percent control				Color ratings			
No.	Type	Name	Rate	Unit	31 DAT		67 DAT		31 DAT		67 DAT	
1	HERB	Envoy	13	fl oz/a	96	a	90	ab	3	d	8	ab
	ADJ	COC	1	% v/v								
2	HERB	Envoy	15	fl oz/a	96	a	93	ab	3	d	5	ab
	ADJ	COC	1	% v/v								
3	HERB	Envoy	17	fl oz/a	98	a	96	a	3	d	5	ab
	ADJ	COC	1	% v/v								
4	HERB	Outrider	0.5	oz/a	91	abc	92	ab	4	cd	8	a
	ADJ	NIS	0.5	% v/v								
5	HERB	Outrider	0.75	oz/a	92	ab	93	ab	5	bcd	7	ab
	ADJ	NIS	0.5	% v/v								
6	HERB	Outrider	1	oz/a	90	abc	98	a	4	cd	4	b
	ADJ	NIS	0.5	% v/v								
7	HERB	Outrider Spot	1	oz/100 gal	91	abc	93	ab	5	bc	8	a
	ADJ	NIS	0.5	% v/v								
8	HERB	Fusion	7	fl oz/a	95	a	96	a	3	d	8	ab
	ADJ	NIS	0.25	% v/v								
9	HERB	Fusion	9	fl oz/a	95	a	98	a	3	d	8	ab
	ADJ	NIS	0.25	% v/v								
10	HERB	Outrider	0.5	oz/a	75	c	77	bc	5	bcd	8	ab
	HERB	MSMA	32	fl oz/a								
11	HERB	MSMA	32	fl oz/a	78	bc	70	c	6	ab	8	a
12	CHK	Untreated Check			0		0		8	a	8	a

Note: Values followed by the same letter at a given time interval are not statistically significantly different at the p = 0.05 level using Fishers LSD test.

Fescue injury appeared to decrease as the trial progressed through 2 months for all treatments except Outrider at 1 oz / ac (Table 4). This is unlike the response seen at Central City. This again may be due to the different environmental conditions between the two sites as central Kentucky received a considerable amount of precipitation throughout the summer as compared to Central City. The Outrider spot treatment (treatment 7) appears to effective in controlling Johnsongrass while minimizing fescue injury. This control option is dependent on accurate identification and cost efficacy is dependent on plant density.

Summary

Outrider appears to be an effective control option for Johnsongrass. Fescue injury will occur initially but lessens as time after treatment increases. Fescue injury appears to be affected by the amount of precipitation after application. In areas of the state that are prone to dry summers this response may have to be accepted as injury occurred with all treatments tested. There was no statistically significant difference of control between the Outrider 0.75 and 1 oz / ac treatments approximately 2 months after application at both the Central City and Spindletop trials. Outrider at 0.75 oz / ac is similar in cost to Fusion at 9 oz / ac and produces similar results. This treatment appears to be suitable as a annual rotation partner with Fusion reduce the probability of resistant Johnsongrass from appearing on KTC rights-of-way.

The Outrider spot treatment was effective in controlling Johnsongrass and reducing fescue injury by eliminating the broadcast application. This treatment would be effective in small infestations.

It is unclear if Outrider would provide residual control of Johnsongrass rhizomes and regrowth of Johnsongrass the season following application. The Spindletop trial will be maintained throughout the winter of 2004 – 2005 and examined in the spring / summer of 2005.

Literature Cited

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Control of Canada Thistle (*Cirsium arvense*)

Introduction

Canada thistle is a federally listed invasive species native to Europe, western Asia, and northern Africa. First introduced into North America as an impurity in imported crop seeds, it was seen as a problem weed in agricultural settings as early as the late 1700s (Anderson 1999). This perennial has now become established and / or naturalized in Canada and areas north of the 37th parallel in the United States (roughly the southern border of Virginia, Missouri, Colorado, Utah, and through the middle of California). This species can aggressively spread by wind carried seeds and sprouting rhizomes, making it troublesome to control. In Kentucky, Canada thistle is more common in the northern and central regions of the state but does occur throughout the state in selected areas. It is possible that the species was accidentally planted along side KTC rights-of-way through the use of contaminated straw during construction remediation.

Certain growth regulator type herbicides have been shown to be effective on Canada thistle. Donald (1993) showed that dicamba, clopyralid, and picloram were all effective in reducing Canada thistle stem density after annual fall applications repeated for three years. 2,4-D was less effective in this study indicating that not all growth regulator type herbicides are equally as effective. Beck and Sebastian (2000) showed similar results with picloram. Beck and Sebastian also showed that this efficacy is neither increased nor decreased when Canada thistle is mowed 5-6 weeks prior to herbicide application.

Two studies are presented here. The first focuses on growth regulator type herbicides (2,4-D, dicamba, etc) while the second focuses on PPO inhibitor herbicides.

Control of Canada thistle with growth regulator type herbicides

Methods and Materials

A randomized complete block design study with three replications was installed at Spindletop research farm in Lexington, KY in early July 2004. The study site was a field with a predominant tall fescue cover with an even distribution of Canada thistle across the site. Eight chemical treatments and one untreated control were evaluated at 20 GPA (Table 1) and all chemical treatments included a non-ionic surfactant at 0.25 % v/v. Stinger was used in lieu of Transline, the non-crop labeled clopyralid. Plots were 5' X 20' and treated with a CO_2 powered sprayer equipped with three TeeJet 8004 flat fan nozzles. Plots were evaluated 62 and 100 DAT for visual percent control of Canada thistle and data was analyzed using ARM software. Treatment means were compared using Fisher's LSD at the $p = 0.05$ level. Untreated control values were omitted during analysis to reduce variance.

Results

There was variation in the amount of control seen at 62 DAT (Table 2). Control ranged from 17 % for Overdrive at 6 oz / ac to 91 % for Overdrive + Stinger at 4 oz + 8 oz / ac. This variation in response decreases as the trial progressed to 100 DAT. All treatments including clopyralid controlled at least 90 % of the Canada thistle. There appears to be no added benefit from increasing the amount of clopyralid in the Overdrive + Stinger treatments as the control response seen between the two treatments is not significantly different at 62 or 100 DAT. Although not statistically significant, there does appear to be some benefit to adding clopyralid to the Overdrive treatments as the lower rate (4 oz) resulted in a higher response when tank mixed with clopyralid than Overdrive alone at 6 oz. Clopyralid alone resulted in high control percentages at 100 DAT; however, the addition of Overdrive at 4 oz to the lower rate of clopyralid (8 fl oz) resulted in high percent control sooner than clopyralid alone. There was no statistically significant difference between the Overdrive alone treatments, Overdrive + Stinger treatments, Stinger alone, and Overdrive + Redeem R&P treatment at 100 DAT. The Garlon 4 treatment showed satisfactory control at 100 DAT but never realized the level of control as the other treatments tested.

There is considerable cost per acre variation across the treatments (Table 1). Based on level of control at 100 DAT, cost per acre, and statistical comparisons of treatment means, Overdrive alone with a non-ionic surfactant provides an operationally satisfactory level of control. Higher levels of control are seen with clopyralid alone and when Overdrive is tank mixed with clopyralid. The need to add Overdrive to clopyralid will depend on site characteristics such as weed populations not controlled by clopyralid alone or presence of desirables that may be injured with Overdrive.

Table 1: Treatment list for growth regulator Canada thistle trial

Treatment	Compounds	Active Ingredients	Rate per acre	Cost per acre
1	Overdrive + COC	diflufenzopyr + dicamba	6 oz + 32 fl oz	$17.00
2	Overdrive + NIS	diflufenzopyr + dicamba	6 oz + 32 fl oz	$15.00
3	Overdrive + Garlon 4 + COC	diflufenzopyr + dicamba + triclopyr	4 oz + 16 fl oz + 32 fl oz	$23.00
4	Garlon 4 + COC	triclopyr	16 fl oz + 32 fl oz	$13.00
5	Overdrive + Stinger + COC	diflufenzopyr + dicamba + clopyralid	4 oz + 10.67 fl oz + 32 fl oz	$35.00
6	Overdrive + Stinger + COC	diflufenzopyr + dicamba + clopyralid	4 oz + 8 fl oz + 32 fl oz	$29.00
7	Stinger + COC	clopyralid	10.67 fl oz + 32 fl oz	$25.00
8	Overdrive + Redeem R&P + COC	diflufenzopyr + dicamba + clopyralid + triclopyr	4 oz + 32 fl oz + 32 fl oz	$38.00
9	Untreated			

Table 2: Summary results for growth regulator Canada thistle trial

Trt No.	Type	Treatment Name	Rate	Rate Unit	Percent Control 62 DAT		100 DAT	
1	HERB	Overdrive	6	oz/a	17	cd	88	ab
	ADJ	COC	32	fl oz/a				
2	HERB	Overdrive	6	oz/a	22	bc	87	ab
	ADJ	NIS	0.25	% v/v				
3	HERB	Overdrive	4	oz/a	35	bc	70	bc
	HERB	Garlon EC	16	fl oz/a				
	ADJ	COC	32	fl oz/a				
4	HERB	Garlon EC	16	fl oz/a	32	bc	67	c
	ADJ	COC	32	fl oz/a				
5	HERB	Overdrive	4	oz/a	88	a	90	a
	HERB	Stinger	10.67	fl oz/a				
	ADJ	COC	32	fl oz/a				
6	HERB	Overdrive	4	oz/a	91	a	93	a
	HERB	Stinger	8	fl oz/a				
	ADJ	COC	32	fl oz/a				
7	HERB	Stinger	10.67	fl oz/a	42	b	95	a
	ADJ	COC	32	fl oz/a				
8	HERB	Overdrive	4	oz/a	83	a	93	a
	HERB	Redeem R & P	32	fl oz/a				
	ADJ	COC	32	fl oz/a				
9	CHK	Untreated Check			0	d	0	d

Note: Values followed by the same letter at a given time interval are not statistically significantly different at the p = 0.05 level using Fisher's LSD.

Control of Canada thistle with protoporphyinogen oxidase (PPO) inhibitor herbicides

Materials and Methods

A study was installed in June 2004 to evaluate the efficacy of the PPO type herbicides for Canada thistle control. This family of herbicide chemistry has been historically been used strictly in agricultural settings. Examples include acifluorfen, fomesafen, lactofen, and oxyfluorfen. These herbicides are extremely effective in the controlling annuals but it is unclear if these chemistries could be a cost effective treatment for troublesome species such as Canada thistle at low rates. This trial examines the efficacy of this specific chemistry in controlling Canada thistle.

Sixteen chemical treatments and an untreated control where installed in a randomized complete block design with three replications on June 17th, 2004. Plots were 10’ X 30’ with a 5’ running check between each plot. Treatments were applied using an ATV equipped with a CO_2 powered sprayer using TeeJet XP size 03 flat fan tips. Applications were made at 20 GPA. Table 1 shows the products and rates used and costs are included for comparison purposes only. All treatments except those containing MSMA included a nonionic surfactant at a rate of 0.25% v/v and add an approximate cost of $0.25 per acre.

Quicksilver, Speedzone, and Edict have active ingredients that are considered to be PPO inhibitors. Speedzone is a 4 way blend of cafentrazone ethyl, 2,4-D 2-ethylhexyl ester, mecoprop acid, and dicamba. Hi Dep is a 2,4-D formulation that includes dimethylamine salt of 2,4-D and a diethanolamine salt of 2,4-D.

Data were collected at 29 DAT and 78 DAT. Visual percent control of Canada thistle was recorded and the data analyzed using ARM analysis of variance and treatment means were compared using Fisher’s LSD test at $p = 0.05$. Untreated values were omitted from analysis to reduce variance.

Results

The only treatments that provided control greater than 70 % at 29 DAT where those containing Telar, the Hi Dep alone treatment at 64 fl oz / ac, and Redeem R & P treatment (Table 2). These treatments all declined in percent control 78 DAT to less than 40 %. The treatments with the highest percent control 78 DAT were the Speedzone treatments at 64 and 96 fl oz / ac. This higher degree of control as compared to the Quicksilver and Edict treatments may be due to the 4 way blend mixture in Speedzone. The dicamba element in this product may aid in increasing levels of control. The Redeem R & P treatment decreased in control levels from 29 to 78 DAT. In the previous Canada thistle study, Redeem R & P was effective at a rate 2X that tested here and when mixed with Overdrive.

The inability of foliar applied PPO type herbicides to translocate hinders the efficacy of these compounds in controlling perennials such as Canada thistle. The two way formulation of 2,4-D in Hi Dep was ineffective in controlling Canada thistle which is consistent with results from other 2,4-D studies on Canada thistle. Overdrive, Redeem R & P, and Telar were ineffective in this study. This may be due to the low rates tested in an effort to reduce cost as these chemistries, especially Overdrive, have been shown to be effective in controlling Canada thistle.

Table 1: Treatment list for PPO Canada thistle trial

Treatment	Compounds	Active ingredient(s)	Rate per acre	Cost per acre
1	Quicksilver	carfentrazone	1 fl oz	$5.00
2	Quicksilver	carfentrazone	2 fl oz	$10.00
3	Quicksilver + Hi Dep	carfentrazone + 2,4-D*	1 fl oz + 32 fl oz	$10.00
4	Speedzone	4 way blend**	64 fl oz	$25.00
5	Speedzone	4 way blend**	96 fl oz	$37.00
6	Speedzone + Telar	4 way blend** + chlorsulfuron	96 fl oz + 0.25 oz	$42.00
7	Hi Dep	2,4-D*	32 fl oz	$5.00
8	Hi Dep	2,4-D*	64 fl oz	$10.00
9	Hi Dep + MSMA	2,4-D* + MSMA	32 fl oz + 64 fl oz	$14.00
10	Hi Dep + Overdrive	2,4-D* + diflufenzopyr + dicamba	32 fl oz + 4 oz	$15.00
11	Hi Dep + Telar	2,4-D* + chlorsulfuron	32 fl oz + 0.25 fl oz	$10.00
12	Redeem R & P	clopyralid + triclopyr	16 fl oz	$14.00
13	Edict	pyraflufen	2.75 fl oz	$13.00
14	Edict + Overdrive	pyraflufen + diflufenzopyr + dicamba	2.75 fl oz + 4 oz	$23.00
15	Edict + MSMA	pyraflufen + MSMA	2.75 fl oz + 64 fl oz	$22.00
16	Edict + Telar	pyraflufen + chlorsulfuron	2.75 fl oz + 0.25 oz	$18.00
17	Untreated control			

Table 2: Results summary of PPO Canada thistle trial

Trt No.	Type	Treatment Name	Rate	Rate Unit	Percent Control 29 DAT		Percent Control 78 DAT	
1	HERB	Quicksilver	1	fl oz/a	2	g	28	ab
	ADJ	NIS	0.25	% v/v				
2	HERB	Quicksilver	2	fl oz/a	5	fg	37	ab
	ADJ	NIS	0.25	% v/v				
3	HERB	Quicksilver	1	fl oz/a	52	bcd	25	ab
	HERB	Hi Dep	32	fl oz/a				
	ADJ	NIS	0.25	% v/v				
4	HERB	Speedzone	64	fl oz/a	53	bcd	55	a
	ADJ	NIS	0.25	% v/v				
5	HERB	Speedzone	96	fl oz/a	23	efg	55	a
	ADJ	NIS	0.25	% v/v				
6	HERB	Speedzone	96	fl oz/a	73	ab	12	ab
	HERB	Telar	0.25	oz/a				
	ADJ	NIS	0.25	% v/v				
7	HERB	Hi Dep	32	fl oz/a	28	def	17	ab
	ADJ	NIS	0.25	% v/v				
8	HERB	Hi Dep	64	fl oz/a	77	ab	15	ab
	ADJ	NIS	0.25	% v/v				
9	HERB	Hi Dep	32	fl oz/a	40	cde	5	b
	HERB	MSMA	64	fl oz/a				
10	HERB	Hi Dep	32	fl oz/a	52	bcd	10	b
	HERB	Overdrive	4	oz/a				
	ADJ	NIS	0.25	% v/v				
11	HERB	Hi Dep	32	fl oz/a	87	a	38	ab
	HERB	Telar	0.25	oz/a				
	ADJ	NIS	0.25	% v/v				
12	HERB	Redeem R & P	16	fl oz/a	72	ab	18	ab
	ADJ	NIS	0.25	% v/v				
13	HERB	Edict	2.75	fl oz/a	10	fg	43	ab
	ADJ	NIS	0.25	% v/v				
14	HERB	Edict	2.75	fl oz/a	57	bc	40	ab
	HERB	Overdrive	4	oz/a				
	ADJ	NIS	0.25	% v/v				
15	HERB	Edict	2.75	fl oz/a	5	fg	22	ab
	HERB	MSMA	64	fl oz/a				
16	HERB	Edict	2.75	fl oz/a	73	ab	23	ab
	HERB	Telar	0.25	oz/a				
	ADJ	NIS	0.25	% v/v				
17	CHK	Untreated Check			0		0	

Note: Values followed by the same letter at a given time interval are not statistically significantly different at the p = 0.05 level using Fisher's LSD.

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Total Vegetation Control for Industrial Sites

Introduction

The need for total vegetation control (i.e. bareground) exists for non-crop and industrial sites such as highway rights-of-way, power substations, fencerows, industrial sites such as production plants, and storage facilities to name a few. Total vegetation control is an important management objective in terms of safety and maintenance. For example, vegetation growing in and around an electric substation is a fire hazard and can cause damage to vital components thus increasing maintenance costs. In terms of highways, maintaining a vegetative free zone along highways and underneath guardrails increases driver's line of sight, increases the potential for fires along the highways due to accidents, and allows for a clear vehicle recovery zone. Vegetation growing along the highway is also a maintenance concerns as vegetation can increase the amount of cracks along a paved surface that would allow for the penetration of water into the pavement. This water can create a further maintenance concern if the water is allowed to contract and expand through thawing and freezing cycles. These examples illustrate how the simple presence of vegetation in unwanted areas can create costly problems that could have been avoided.

Applications of broad spectrum residual herbicides have become the mainstay for bareground maintenance operations. Preemergent type herbicides work by inhibiting the germination of seeds present in the soil / strata or being translocated via the roots and/or seed shoots. Examples of these types of herbicides are those containing prodiamine, pendimethalin, bromacil, and oryzalin. If actively growing weeds are present, it is necessary to combine the preemergent compound with a postemergent herbicide such as glyphosate or imazapyr. Many compounds offer both pre and post emergent activity. Examples of these include flumioxazin, diuron, and sulfumeturon. There is a balance in choosing the most effective compounds to create the desired results while minimizing off target damage and cost per acre.

A study was initiated in the spring of 2004 to examine several bareground products and combinations there of for duration of control and cost efficacy.

Materials and Methods

A study was initiated in April of 2005 to compare flumioxazin, pendimethalin, and diuron as bareground products for length of control. The study site was an unused storage area along Interstate 75 in central Kentucky. The study site had areas completely covered with herbaceous vegetation while other areas completely void of vegetation. The substrate was a compacted gravel base with little to no soil present with essentially no slope differences within and between the study blocks. Twenty seven chemical treatments and one untreated control were utilized in a completely randomized block design with three replications (Table 1). Predominant vegetation included decumbent lespedeza, white and red clover, and tall fescue. Plots were 3.3' X 20' with 5' running checks in between plots. Applications were made on April 20th, 2004 using a CO_2 powered sprayer equipped with 2 TeeJet 8008 SS flat fan nozzles at 50 GPA. All treatments included a nonionic surfactant at 0.25 % v/v. Costs per acre are approximate and are for comparison purposes only.

Table 1: Treatment list for 2004 bareground trial

Treatment	Compound	Active Ingredient(s)	Rate per acre	Cost per acre
1	Payload + Arsenal	flumioxazin + imazapyr	8 oz + 12 fl oz	$71.00
2	Payload + Arsenal	flumioxazin + imazapyr	8 oz + 16 fl oz	$77.00
3	Payload + Arsenal	flumioxazin + imazapyr	8 oz + 32 fl oz	$106.00
4	Payload + Arsenal	flumioxazin + imazapyr	10 oz + 12 fl oz	$82.00
5	Payload + Arsenal	flumioxazin + imazapyr	10 oz + 16 fl oz	$89.00
6	Payload + Arsenal	flumioxazin + imazapyr	10 oz + 32 fl oz	$118.00
7	Payload + Arsenal	flumioxazin + imazapyr	12 oz + 12 fl oz	$94.00
8	Payload + Arsenal	flumioxazin + imazapyr	12 oz + 16 fl oz	$101.00
9	Payload + Arsenal	flumioxazin + imazapyr	12 oz + 32 fl oz	$130.00
10	Payload	flumioxazin	8 oz	$49.00
11	Payload	flumioxazin	10 oz	$61.00
12	Payload	flumioxazin	12 oz	$73.00
13	Payload + Oust	flumioxazin + sulfumeturon	8 oz + 3 oz	$81.00
14	Payload + Oust	flumioxazin + sulfumeturon	10 oz + 3 oz	$93.00
15	Payload + Oust	flumioxazin + sulfumeturon	12 oz + 3 oz	$105.00
16	Payload + RoundUp Pro	flumioxazin + glyphosate	8 oz + 64 fl oz	$71.00
17	Payload + RoundUp Pro	flumioxazin + glyphosate	10 oz + 64 fl oz	$83.00
18	Payload + RoundUp Pro	flumioxazin + glyphosate	12 oz + 64 fl oz	$95.00
19	Pendulum AquaCap + Arsenal	pendimethalin + imazapyr	64 fl oz + 12 fl oz	$46.00
20	Pendulum AquaCap + Arsenal	pendimethalin + imazapyr	64 fl oz + 16 fl oz	$53.00
21	Pendulum AquaCap + Arsenal	pendimethalin + imazapyr	128 fl oz + 12 fl oz	$70.00
22	Pendulum AquaCap + Arsenal	pendimethalin + imazapyr	128 fl oz + 16 fl oz	$77.00
23	Sahara	diuron + imazapyr	12 lb	$107.00
24	Sahara	diuron + imazapyr	16 lb	$143.00
25	Sahara + RoundUp Pro	diuron + imazapyr + glyphosate	12 lb + 64 fl oz	$130.00
26	Sahara + RoundUp Pro	diuron + imazapyr + glyphosate	16 lb + 64 fl oz	$165.00
27	Endurance + Arsenal	prodiamine + imazapyr	2 lb + 12 fl oz	$83.00
28	Untreated			

Data collection included pre-application measurement of cover by species, percent cover of dead vegetation, and percent cover bareground. Follow up measurements were taken at approximately two week intervals after treatment. Data were analyzed using analysis of covariance (pre-application data as the covariate) in SAS software and adjusted treatment means were compared at each time interval using

Tukey's Honest Significant Difference (HSD) method at $p = 0.05$. Percent cover by species by treatment at 18 WAT was calculated using SAS software and the least square means options to allow for an unbalanced data set.

Results

The treatments that provided the highest level of bareground were those that included sulfumeturon or diuron in the tank mixes (treatments 13 – 15 and 23 – 26) (Table 2). The only treatment other than those containing sulfumeturon (Oust) or diuron (Sahara) that provided a percent cover of bareground greater than 90 % at any time during the screen was the Payload @ 12 oz + Arsenal @ 32 oz. This occurred at both 8WAT and 10 WAT. A general trend exists that shows an increase in percent bareground up to approximately 8 – 10 WAT (depending on treatment and rates). The exception to this is the treatments containing diuron as these treatments show an increase of percent bareground through 12 WAT.

There was no statistically significant difference between any Payload treatments that contained Arsenal at any given time interval. However, the treatments that had the high rate of Arsenal (32 oz) generally had higher percentages of bareground. The Payload alone treatments never realized the same degree of bareground as the Payload tank mix treatments; however, the Payload @ 10 oz per acre treatment (# 11) does show comparable levels of bareground. These stand alone treatments show the need for tank mixing with flumioxazin. The Payload @ 12 oz + RoundUp Pro @ 64 fl oz treatment had a higher, although not statistically significantly different, percent cover of bareground at the 18 WAT interval than the Payload treatments incorporating Arsenal.

Treatments using Pendulum AquaCap generally had lower percentages of bareground cover as compared to treatments using Arsenal or Oust. There appears to be antagonism present in this study in the Pendulum AquaCap treatments as the lower rate tested, 64 fl oz, plus Arsenal at 16 fl oz, had higher, although not statistically significantly different, levels of bareground compared to the treatments using the high rate of Pendulum AquaCap.

Treatments using Sahara consistently provided excellent levels of bareground through the entire screen. As previously stated, these treatments along with those using Oust, provided consistent control of vegetation through 18 WAT. These treatments would be preferable if non target damage due to herbicide movement were not a concern. Herbicide movement has been known to occur for these two products at the rate tested if environmental conditions (slope of treated site, precipitation, etc) favor this type of activity.

The Endurance + Arsenal treatment never a percent cover of bareground greater than 80 % in this trial. This treatment provided levels of bareground that were higher than that of the untreated control yet was never significantly different than the untreated control at a given time period through the length of the trial.

Percent cover by species at the end of the trial (18 WAT) would provide some interesting information. Table 3 shows percent cover by species by treatment for those species that had an adjusted mean percent cover greater than 5 %. These data would allow one to see what species were not controlled, or being "let go", at this time. It is important to remember that this information can not be interpreted across all treatments.

For example, if buckhorn plantain was beginning to occur in the Sahara plots but not in the Payload plots, it does not necessarily mean that Payload is more effective in controlling buckhorn plantain than Sahara. This phenomenon could be because there simply was no buckhorn plantain or an equally high concentration of buckhorn plantain in the Payload plots as the Sahara plots. The percent cover by species values should also not be the focus of this information; the presence of a species is the critical information. These data were not analyzed statistically for significant difference by species across treatments. This would be inaccurate given the size of the study area, the distribution of the weed complex, and the differences of weed density and population across plots at the beginning of the trial. This information is provided simply to give the reader an idea of what species were beginning to occur in certain treatments at 18 WAT.

Future Research

The entire study will be reapplied over the same area in the spring of 2005. The treatments assigned to certain plots will be applied to the same plots. This will give an operational aspect to the study as bareground treatments are typically applied to the same areas every spring. This will also provide periodic data (annual) for these applications. The study site had a broad weed complex and uneven distribution across the site at installation in April 2004. Reapplication of the same treatments will give information on persistence and a compounds ability to "reclaim" a site after sequential annual applications.

Table 2: Adjusted treatment means for percent cover bareground for entire bareground trial

		HSD		HSD		HSD		HSD		HSD		HSD		HSD		HSD
Trt	**2WAT***	**55.25**	**5WAT***	**40.23**	**6WAT***	**43.21**	**8WAT***	**35.78**	**10WAT***	**40.33**	**12WAT***	**58.56**	**14WAT***	**66.18**	**18WAT***	**61.5**
1	52.9	a	62.6	ab	80.1	ab	88.5	ab	88.6	a-c	84.9	a-e	85.0	ab	63.1	a
2	30.0	a	50.2	ab	64.9	a-c	70.3	a-d	84.1	a-c	61.4	a-e	57.9	ab	47.9	a
3	51.3	a	65.3	ab	87.1	a	91.0	ab	91.4	ab	84.2	a-e	84.3	ab	72.3	a
4	45.6	a	63.3	ab	55.8	a-c	79.8	a-d	82.8	a-c	75.5	a-e	83.1	ab	71.7	a
5	27.7	a	48.5	ab	82.5	ab	74.0	a-d	63.2	a-e	49.6	b-e	67.0	ab	50.0	a
6	58.8	a	63.8	ab	77.4	a-c	84.3	a-c	89.4	ab	88.2	a-e	83.8	ab	71.5	a
7	40.6	a	52.0	ab	76.9	a-c	84.8	a-c	85.2	a-c	81.7	a-e	78.1	ab	53.9	a
8	45.9	a	66.0	ab	76.9	a-c	84.5	a-c	77.6	a-d	68.5	a-e	73.3	ab	58.7	a
9	53.9	a	62.4	ab	86.3	a	92.6	ab	97.2	ab	86.6	a-e	86.3	ab	64.4	a
10	21.0	a	18.5	b	28.5	bc	35.1	d	39.8	de	40.5	e	50.7	ab	48.6	a
11	47.1	a	67.3	ab	68.9	a-c	70.8	a-d	80.0	a-c	70.8	a-e	80.6	ab	71.8	a
12	48.2	a	32.3	ab	45.6	a-c	44.9	b-d	46.0	c-e	47.5	c-e	50.0	ab	50.4	a
13	43.3	a	62.8	ab	77.5	a-c	81.0	a-d	90.7	ab	91.4	a-d	88.1	ab	71.8	a
14	44.6	a	59.7	ab	77.0	a-c	87.0	a-c	96.1	ab	93.8	a-d	91.4	ab	87.5	a
15	33.1	a	62.1	ab	84.1	a	93.7	a	98.4	a	98.3	ab	98.2	a	89.7	a
16	54.5	a	63.4	ab	81.8	ab	72.0	a-d	68.8	a-e	64.5	a-e	82.8	ab	60.4	a
17	42.3	a	71.2	ab	68.6	a-c	72.8	a-d	72.0	a-d	66.7	a-e	66.1	ab	42.5	a
18	46.9	a	75.5	ab	89.9	a	79.7	a-d	84.0	a-c	80.0	a-e	84.4	ab	83.8	a
19	34.6	a	45.4	ab	55.2	a-c	55.3	a-d	57.4	b-e	53.1	a-e	63.3	ab	62.9	a
20	27.6	a	49.1	ab	81.6	ab	84.2	a-c	83.7	a-c	78.3	a-e	77.9	ab	69.1	a
21	33.6	a	45.2	ab	62.3	a-c	67.8	a-d	75.7	a-d	68.6	a-e	76.3	ab	62.6	a
22	35.7	a	45.3	ab	59.9	a-c	69.5	a-d	79.1	a-d	69.8	a-e	74.4	ab	64.8	a
23	37.5	a	70.8	ab	77.9	a-c	89.4	ab	97.3	a	93.3	a-d	93.1	ab	82.7	a
24	57.7	a	85.1	a	93.9	a	93.7	a	95.9	ab	95.8	a-c	95.7	a	89.7	a
25	48.9	a	59.2	ab	72.3	a-c	78.2	a-d	100.0	a	99.9	a	97.0	a	88.1	a
26	49.0	a	55.2	ab	75.3	a-c	88.0	ab	100.0	a	100.0	a	99.7	a	91.6	a
27	32.3	a	38.3	ab	61.9	a-c	79.2	a-d	65.9	a-e	64.8	a-e	50.1	ab	59.4	a
28	20.5	a	16.7	b	25.0	c	40.4	cd	32.0	e	45.3	de	45.2	b	55.3	a

Note: Treatment means followed by the same letter are not statistically different using Tukey's Honest Significant Difference Test at $p = 0.05$. An asterick (*) next to evaluation dates indicates statistically significant treatment effect at that evaluation date.

Table 3: Adjusted mean percent cover by species by treatment at 18 WAT

Trt	Species	Cover
1	Lespedeza	35.5
	Crabgrass	7.5
2	Crabgrass	30
	White clover	21
	Yellow foxtail	15.8
	Tall fescue	10
	Lespedeza	10
3	Crabgrass	17.3
	Marestail	7.5
4	Lespedeza	35
	Marestail	10
	Yellow foxtail	7.5
5	Crabgrass	32
	Tall fescue	21
	Marestail	10
	Yellow foxtail	5
6	Crabgrass	10
	Yellow foxtail	6.25
7	Yellow foxtail	33.7
	Crabgrass	21
	White clover	10
8	Lespedeza	21
	Crabgrass	19.5
	Marestail	7.5
9	Crabgrass	35
	Lespedeza	11.75
	Yellow foxtail	10
	Marestail	10
10	White clover	50
	Buckhorn plantain	14.8
	Marestail	10
11	White clover	10
	Buckhorn plantain	10
	Crabgrass	10
	Yellow foxtail	10
	Marestail	6.25
12	White clover	36.7
	Dandelion	10
	Marestail	7.25
	Tall fescue	6.25
13	Crabgrass	21
	Yellow foxtail	15.8
14	Yellow foxtail	15.5
15	Lespedeza	10
	Crabgrass	5
16	Crabgrass	22.5
	Tall fescue	10
	Marestail	7.5
	White clover	6.25
	Yellow foxtail	6.25
17	Crabgrass	36.7
	Marestail	19.5
18	White clover	11.75
	Marestail	10
	Crabgrass	10
	Yellow foxtail	6.25
19	Lespedeza	31
	Marestail	10
	Yellow foxtail	7.5
	Buckhorn plantain	6.25
20	Lespedeza	18.75
	Marestail	18.3
	Buckhorn plantain	6.25
21	Lespedeza	28
	Marestail	11.2
	Carrot	10
	Tall fescue	6.25
22	Marestail	21
	Buckhorn plantain	21
	Lespedeza	10
	White clover	10
	Tall fescue	6.25
	Yellow foxtail	6.25
	Red Clover	6.25
23	Crabgrass	10
	Lespedeza	10
	Tall fescue	10
	Marestail	6.25
	Buckhorn plantain	6.25
24	Buckhorn plantain	6.25
25	Yellow foxtail	10
	Crabgrass	6.25
26	Broomsedge	10
	Buckhorn plantain	6.25
27	Lespedeza	90
	Marestail	5
28	White clover	21
	Lespedeza	15.5
	Crabgrass	10
	Marestail	6.25
	Buckhorn plantain	5

Tall Fescue (*Festuca arundinacea*) Seedhead Suppression with Plant Growth Regulators

Introduction

Plant growth regulators, or PGRs, are an effective tool utilized by vegetation managers in turf, urban forestry, and rights-of-way to reduce the impact that vegetation has on management cycles. Maintenance costs may decrease by reducing the number of mowings or trimmings needed to keep the vegetation clear of sensitive areas. PGRs can be classified as herbicides, since they control vegetation in some manner, and most herbicides, at very low rates, are growth regulators but with a narrow margin of safety. Products that are marketed as PGRs for turf include fluprimidol, mefluidide, and paclobutrazol. Traditional herbicides that include seedhead suppression, or “chemical mowing”, verbiage in their labels include metsulfuron, imazapic, and glyphosate.

PGRs are categorized into two groups; the type I PGRs and the type II PGRs. Type I PGRs suppress growth and development and inhibit cell division while the type II PGRs suppress growth only. Type II PGRs act as gibberellin biosynthesis inhibitors and suppress, not inhibit, cell elongation. Type II PGRs therefore do allow for the development of plant organs, although miniature in size compared to untreated vegetation. Type I PGRs and herbicides for turf include maleic hydrazide, mefluidide, glyphosate, chlorsulfuron, and metsulfuron. Type II PGRs for turf include flurprimidol, paclobutrazol, and triexepac-ethyl.

Highway rights-of-way managers use type I PGRs to inhibit seedhead development and growth of tall fescue in areas that would be otherwise time consuming, and thereby more costly, to mow. These areas would include steep embankments around cloverleafs and areas underneath permanent structures where grass cover is desirable. Timing of application of PGRs for seedhead suppression is critical as seedheads that have already developed in the spring will continue to grow after application. Future seedhead development will be inhibited by most chemicals but the window of application to receive the most net benefit for the application is relatively small (about 4 weeks in the spring or right at green up of the turf). Another concern of applying PGR’s on turf is a discoloration of the vegetative growth; however, the vegetation will return to “normal” color as the growing season progresses. One added benefit is that PGRs, by inhibiting seedhead growth and development, may redirect the energy stores intended for seedheads into the roots and creating a stronger turf in the long run.

Two trials were installed to evaluate several PGRs and herbicides for seedhead suppression in tall fescue. Broadleaf weed control products were tested in combination with the PGRs and other herbicides to detect any differences in removing broadleaf weeds in turf. Discoloration of turf, length of seedhead suppression, and the ability of these products to suppress other grass species seedhead development (i.e. orchardgrass) were also evaluated.

Methods and Materials

Two identical trials were installed with the first at Princeton Research Station in Princeton, KY and the second at Spindletop Research Station in Lexington, KY. Thirty-eight treatments and one untreated control where evaluated in a randomized complete block design with three replications (block being replicates) (Table 1). Plots were 7’ X 25’ with 5’ running checks between plots. Plots were treated with a CO_2 powered sprayer mounted on an ATV. The spray boom was mounted on one side of the ATV so treatments could be made without driving the ATV over the plot area and equipped with TeeJet 8004 flat fan nozzles. Treatments were made at 20 GPA at both sites. Princeton applications were made on April 5th, 2004 and the Spindletop applications were made on April 27th, 2004.

Data collected included turf color using a 0-9 scale (0 = dead, 9 = fully green), percent cover by species, seedhead height, and categorical data on number of seedheads per plot. The categorical groupings for this variable were 0 = no seedheads, 1 = 1 – 5 seedheads, 2 = 6 – 15 seedheads, 3 = 16 – 30 seedheads, and 4 = > 30 seedheads per plot. Categorical data was collected to avoid having to count individual seedheads in each plot. The presence of orchardgrass and Kentucky bluegrass seedheads were noted for each plot at each measurement interval. Data for turf color, seedhead height, and number of seedheads per plot (categorical) were taken every two weeks from time of application up to 10 WAT. After 10 WAT, the presence of tall fescue, orchardgrass, (i.e. seedhead present or not) and turf color was recorded every other week up to 18 WAT. Percent cover by species was taken 1 WAT, 8 WAT, and 17 WAT at the Princeton site and 1 WAT, 9 WAT, and 18 WAT at the Spindletop site.

Data collected was analyzed using several different methodologies. Turf color was analyzed using analysis of variance and treatment means were compared at each time interval using Fisher's LSD method at $p = 0.05$. Seedhead height data was analyzed using the general linearized model procedure in SAS to produce least square means and treatment means were compared using the Tukey-Kramer method at $p = 0.05$. Percent cover by species was analyzed using analysis of covariance with cover at 1 WAT being the covariate. This allowed for the comparison of treatments for broadleaf weed control.

Seedhead count data, which was categorical, was tested for normality using the univariate procedure in SAS® and all categorical data failed to pass the requirements for normality (i.e. data having a normal, or Bell curve distribution). Thus, categorical data collected had to be analyzed using nonparametric techniques. Methods for nonparametric data analysis included the use of the rank procedure, the mixed procedure, and a SAS macro program designed to provided standard errors and relative group effects (Shah and Madden 2004). These specialized SAS programs provided ANOVA type statistics (i.e. the F statistic) to show presence of treatment effect at a given time interval. They also create rank least square means based on the observed categorical data. Rankings show the underlying pattern in the measured response. For example, there are several ways that a treatment in this study could have a mean categorical response of 1 (1 – 5 seedheads per plot). All three replications of the treatment may have been rated as 1 or one replication may have been rated a 3 and the other two a 0. The rank procedure examines the pattern of the data and its relation to both the *mean* and *median* response and assigns ranks accordingly. The least square mean ranks are then evaluated for treatment effect. This allows one to see the effect treatments have using categorical data.

Table 1: Treatment list for seedhead suppression trial

Treatment	Product	Rate per acre	Estimated cost per acre
1	Stronghold	8 fl oz	$13.00
2	Stronghold	12 fl oz	$19.00
3	Stronghold	16 fl oz	$26.00
4	Stronghold + Telar	4 fl oz + 0.125 oz	$9.00
5	Stronghold + Telar	6 fl oz + 0.125 oz	$12.00
6	Stronghold + Telar	8 fl oz + 0.125 oz	$16.00
7	Stronghold + Telar	4 fl oz + 0.25 oz	$12.00
8	Stronghold + Telar	6 fl oz + 0.25 oz	$15.00
9	Stronghold + Telar	8 fl oz + 0.25 oz	$18.00
10	Stronghold + HiDep	8 fl oz + 32 fl oz	$18.00
11	Stronghold + HiDep	12 fl oz + 32 fl oz	$24.00
12	Stronghold + HiDep	16 fl oz + 32 fl oz	$30.00
13	Stronghold + HiDep	8 fl oz + 64 fl oz	$22.00
14	Stronghold + HiDep	12 fl oz + 64 fl oz	$29.00
15	Stronghold + HiDep	16 fl oz + 64 fl oz	$35.00
16	Stronghold + Escort	2 fl oz + 0.25 oz	$8.00
17	Stronghold + Escort	3 fl oz + 0.25 oz	$10.00
18	Stronghold + Escort	4 fl oz + 0.25 oz	$11.00
19	Stronghold + Escort	2 fl oz + 0.5 oz	$13.00
20	Stronghold + Escort	3 fl oz + 0.5 oz	$14.00
21	Stronghold + Escort	4 fl oz + 0.5 oz	$16.00
22	Plateau	1 fl oz	$3.00
23	Plateau	2 fl oz	$5.00
24	Plateau	3 fl oz	$7.00
25	Plateau	4 fl oz	$9.00
26	Plateau + Escort	1 fl oz + 0.25 oz	$7.00
27	Plateau + Escort	2 fl oz + 0.25 oz	$9.00
28	Plateau + Escort	3 fl oz + 0.25 oz	$11.00
29	Plateau + Escort	4 fl oz + 0.25 oz	$13.00
30	Plateau + Escort	1 fl oz + 0.5 oz	$11.00
31	Plateau + Escort	2 fl oz + 0.5 oz	$14.00
32	Plateau + Escort	3 fl oz + 0.5 oz	$16.00
33	Plateau + Escort	4 fl oz + 0.5 oz	$18.00
34	Escort	0.25 oz	$5.00
35	Escort	0.33 oz	$6.00
36	Escort	0.5 oz	$9.00
37	RoundUp Pro	6 fl oz	$2.00
38	RoundUp Pro	8 fl oz	$3.00
40	Untreated		

Results

Princeton PGR trial results

The timing of applications of plant growth regulators for seedhead suppression in tall fescue stands is critical. The timing of the application for the Princeton trial appeared to be very accurate as initial seedhead growth inhibition was excellent for the majority of the treatments at 4 WAT (Table 2). Three Stronghold treatments, 2, 15, and 17, inhibited the development and growth of seedheads through 10 WAT. Several Plateau treatments (treatments 24, 25, 26, 28, 29, 31, and 33) successfully prevented seedhead growth through 10 WAT. No one Escort alone treatment or RoundUp Pro treatment could inhibit seedhead development through 10 WAT. A Stronghold + Escort treatment, 21, was able to prevent the growth of new seedheads after application as mean seedhead height declined to 0 cm at 6 WAT and maintained this through 10 WAT. A Plateau treatment, 23, was able to perform in the same manner. It is important to remember when reading this table that the important fact is the absence of seedheads and not the height of the seedheads.

Table 3 shows density of seedheads based on the categorical data analysis for time intervals with significant treatment effect. This table mimics Table 2 in that treatments with a mean seedhead height of 0 cm will have a mean density category of 0. Table 3 has been sorted by mean rank and its corresponding treatment effect. The **lower the rank** (and its corresponding treatment effect) **the better the treatment was in suppressing seedhead development and growth.** The purpose of this table is to give the reader an idea of the gradient of treatments from more effective to less effective.

As stated previously in the methods section, data collected on seedhead presence after 10 WAT only noted the presence or absence of tall fescue seedheads. Table 4 summarizes the presence of tall fescue seedheads in all plots. Ordinal means data can be interpreted as fractions; that is, an ordinal mean of 0.67 means 2/3^{rds} of the plots for that treatment released seedheads. Six treatments were effective in tall fescue seedhead suppression on all three replications at 17 WAT (Table 4). These included two Stronghold + Escort treatments (treatments 17 & 20), two Plateau treatments (treatments 24 & 25), and two Plateau + Escort treatments (treatments 29 & 33). Stronghold @ 12 oz was able to suppress all seedheads in all plots up to 15 WAT. Plateau @ 3 and 4 oz (treatments 24 and 25) suppressed tall fescue seedhead through the entire trial but at the expense of early discoloration (Table 5)

Vegetative color was severely affected by most all treatments at 4 WAT (Table 5). Only 2 treatments (1 and 30) had mean color ratings above 5 at 4 WAT. A mean color rating below 5 is considered operationally unacceptable. These discolorations were temporary as all treatments had color ratings above 5 by 10 WAT.

There was no significant difference in the percent cover of broadleaf weeds when evaluated throughout the trial. This is due to the abundance of cover of tall fescue (> 95 %) throughout the trial. The addition of Escort as a broadleaf weed control product at the rates tested does not appear to influence the efficacy of the PGR. Higher rates of Escort will damage tall fescue. The Stronghold + Telar and Stronghold + HiDep treatments were not as effective in seedhead suppression past 8 WAT as other Stronghold treatments. The Escort alone and RoundUp Pro treatments were not effective in tall fescue seedhead suppression at rates tested.

No one treatment tested here could effectively suppress orchardgrass seedheads.

Table 2: Adjusted mean seedhead height (cm) by treatment for Princeton PGR trial

Mixture	Treatment	4WAT		6WAT		8WAT		10WAT	
Stronghold	1	20.7	a-c	67.9	ab	79.8	ab	79.4	ab
	2	0	c	0	c	0	d	0	c
	3	0	c	61.9	a-c	74.9	a-c	31.4	a-c
Stronghold + Telar	4	0	c	42	a-d	49.6	a-d	58.4	a-c
	5	0	c	0	c	17.3	cd	42	a-c
	6	0	c	0	c	53.4	a-d	56.1	a-c
	7	20	bc	46.6	a-d	36.6	a-d	38	a-c
	8	0	c	0	c	37.8	a-d	47.6	a-c
	9	13.3	c	66.75	ab	66	a-c	70.7	ab
Stronghold + HiDep	10	0	c	30.3	b-d	60.8	a-d	60.3	a-c
	11	0	c	0	c	34.5	a-d	24.3	bc
	12	0	c	0	c	0	d	37	a-c
	13	0	c	0	c	57.3	a-d	60.8	a-c
	14	0	c	0	c	50.6	a-d	40.6	a-c
	15	0	c	0	c	0	d	0	c
Stronghold + Escort	16	0	c	30	b-d	77.1	a-c	76.6	ab
	17	0	c	0	c	0	d	0	c
	18	0	c	0	c	0	d	27.3	bc
	19	0	c	13.7	cd	0	d	23	bc
	20	0	c	24.5	b-d	35.7	a-d	42	a-c
	21	34	a-c	0	c	22.6	b-d	0	c
Plateau	22	0	c	0	c	0	d	27.7	bc
	23	34.2	ab	0	c	0	d	0	c
	24	0	c	0	c	0	d	0	c
	25	0	c	0	c	0	d	0	c
Plateau + Escort	26	0	c	0	c	0	d	0	c
	27	0	c	0	c	35.4	a-d	26.7	bc
	28	0	c	0	c	0	d	0	c
	29	0	c	0	c	0	d	0	c
	30	21.7	a-c	53.6	a-c	29	b-d	60	a-c
	31	0	c	0	c	0	d	0	c
	32	0	c	15.8	cd	21.8	b-d	0	c
	33	0	c	0	c	0	d	0	c
Escort	34	0	c	64.9	ab	80.6	ab	77.3	ab
	35	11.3	c	68.5	ab	57.5	a-d	65.6	ab
	36	0	c	55.9	a-c	67.7	a-c	65.5	ab
RoundUp Pro	37	0	c	67.1	ab	79.3	ab	80.9	ab
	38	59.3	ab	55.9	a-c	66	a-c	68.6	ab
Untreated	40	65.3	a	79.4	a	92.1	a	94.8	a

Note: Treatment means followed by the same letter are not statistically different at $p = 0.05$ using Tukey-Kramer HSD

Table 3: Tall fescue seedhead density rank means by treatment for Princeton PGR trial

6WAT				8WAT				10WAT			
Treatment	Ordinal Mean	Rank Mean	Treatment effect[1]	Treatment	Ordinal Mean	Rank Mean	Treatment effect[1]	Treatment	Ordinal Mean	Rank Mean	Treatment effect[1]
2	0.00	41.00	0.35 (0.02)	2	0.00	36.00	0.30 (0.04)	2	0.00	34.50	0.29 (0.04)
5	0.00	41.00	0.35 (0.02)	12	0.00	36.00	0.30 (0.04)	15	0.00	34.50	0.29 (0.04)
6	0.00	41.00	0.35 (0.02)	15	0.00	36.00	0.30 (0.04)	17	0.00	34.50	0.29 (0.04)
8	0.00	41.00	0.35 (0.02)	17	0.00	36.00	0.30 (0.04)	21	0.00	34.50	0.29 (0.04)
11	0.00	41.00	0.35 (0.02)	18	0.00	36.00	0.30 (0.04)	23	0.00	34.50	0.29 (0.04)
12	0.00	41.00	0.35 (0.02)	21	0.33	36.00	0.30 (0.04)	24	0.00	34.50	0.29 (0.04)
13	0.00	41.00	0.35 (0.02)	22	0.00	36.00	0.30 (0.04)	25	0.00	34.50	0.29 (0.04)
14	0.00	41.00	0.35 (0.02)	23	0.00	36.00	0.30 (0.04)	26	0.00	34.50	0.29 (0.04)
15	0.00	41.00	0.35 (0.02)	25	0.33	36.00	0.30 (0.04)	28	0.00	34.50	0.29 (0.04)
17	0.00	41.00	0.35 (0.02)	27	0.67	36.00	0.30 (0.04)	29	0.00	34.50	0.29 (0.04)
18	0.00	41.00	0.35 (0.02)	28	0.00	36.00	0.30 (0.04)	31	0.00	34.50	0.29 (0.04)
21	0.00	41.00	0.35 (0.02)	29	0.00	36.00	0.30 (0.04)	32	0.00	34.50	0.29 (0.04)
23	0.00	41.00	0.35 (0.02)	31	0.00	36.00	0.30 (0.04)	33	0.00	34.50	0.29 (0.04)
24	0.00	41.00	0.35 (0.02)	5	0.33	50.33	0.43 (1.69)	3	0.33	49.00	0.42 (1.72)
25	0.00	41.00	0.35 (0.02)	8	0.33	50.33	0.43 (1.69)	11	0.33	49.00	0.42 (1.72)
26	0.00	41.00	0.35 (0.02)	11	0.33	50.33	0.43 (1.69)	12	0.33	49.00	0.42 (1.72)
27	0.00	41.00	0.35 (0.02)	19	0.00	50.33	0.43 (1.69)	14	0.33	49.00	0.42 (1.72)
28	0.00	41.00	0.35 (0.02)	20	0.33	50.33	0.43 (1.69)	18	0.33	49.00	0.42 (1.72)
29	0.00	41.00	0.35 (0.02)	24	0.00	50.33	0.43 (1.69)	19	0.33	49.00	0.42 (1.72)
31	0.00	41.00	0.35 (0.02)	30	0.33	50.33	0.43 (1.69)	20	0.33	49.00	0.42 (1.72)
32	0.00	41.00	0.35 (0.02)	32	0.33	50.33	0.43 (1.69)	22	0.33	49.00	0.42 (1.72)
33	0.00	41.00	0.35 (0.02)	33	0.33	50.33	0.43 (1.69)	27	0.33	49.00	0.42 (1.72)
4	0.33	56.00	0.47 (1.82)	4	0.67	54.50	0.46 (2.80)	5	0.67	53.50	0.45 (2.95)
10	0.33	56.00	0.47 (1.82)	6	0.67	54.50	0.46 (2.80)	7	0.67	53.50	0.45 (2.95)
16	0.33	56.00	0.47 (1.82)	7	0.67	54.50	0.46 (2.80)	6	1.00	56.67	0.48 (4.03)
19	0.33	56.00	0.47 (1.82)	14	0.67	54.50	0.46 (2.80)	4	0.67	63.50	0.54 (1.73)
20	0.33	56.00	0.47 (1.82)	26	0.00	54.50	0.46 (2.80)	8	0.67	63.50	0.54 (1.73)
7	1.33	64.83	0.55 (4.66)	10	0.67	64.67	0.55 (1.70)	30	1.00	68.00	0.58 (2.41)
30	1.33	64.83	0.55 (4.66)	3	2.00	79.17	0.67 (4.03)	9	1.33	72.50	0.62 (2.95)
22	0.67	71.00	0.60 (1.82)	9	2.00	79.17	0.67 (4.03)	1	2.00	79.33	0.67 (0.27)
9	1.67	93.00	0.79 (0.11)	35	2.33	81.83	0.70 (4.38)	13	1.33	82.50	0.70 (0.19)
1	2.33	99.33	0.85 (0.09)	13	1.33	83.17	0.71 (0.18)	10	1.67	85.67	0.73 (0.48)
36	2.33	99.33	0.85 (0.09)	16	2.00	89.33	0.76 (0.87)	16	2.33	93.83	0.80 (0.76)
38	2.33	99.33	0.85 (0.09)	1	2.67	97.67	0.83 (0.30)	35	3.00	101.00	0.86 (0.03)
3	2.67	101.83	0.87 (0.22)	36	3.33	103.00	0.88 (0.11)	36	3.33	104.67	0.89 (0.11)
35	2.67	101.83	0.87 (0.22)	38	3.33	103.00	0.88 (0.11)	38	3.33	104.67	0.89 (0.11)
37	3.00	103.67	0.88 (0.61)	34	3.67	106.50	0.91 (0.10)	34	3.67	108.33	0.92 (0.10)
34	3.33	107.50	0.92 (0.07)	37	4.00	110.00	0.94 (0.02)	37	3.67	108.33	0.92 (0.10)
40	4.00	112.50	0.96 (0.01)	40	4.00	110.00	0.94 (0.02)	40	4.00	112.00	0.95 (0.01)

[1] *Numbers in parentheses are the standard error of the rank means (lower is better)*

Table 4: Presence or absence of tall fescue seedheads by treatment at end of Princeton PGR trial

12WAT				15WAT				17WAT			
Treatment	Ordinal Mean	Rank Mean	Treatment effect[1]	Treatment	Ordinal Mean	Rank Mean	Treatment effect[1]	Treatment	Ordinal Mean	Rank Mean	Treatment effect[1]
2	0.00	28.50	0.24 (0.04)	2	0.00	32.50	0.27 (0.04)	17	0.00	30.00	0.25 (0.06)
15	0.00	28.50	0.24 (0.04)	11	0.00	32.50	0.27 (0.04)	20	0.00	30.00	0.25 (0.06)
18	0.00	28.50	0.24 (0.04)	18	0.00	32.50	0.27 (0.04)	24	0.00	30.00	0.25 (0.06)
24	0.00	28.50	0.24 (0.04)	21	0.00	32.50	0.27 (0.04)	25	0.00	30.00	0.25 (0.06)
25	0.00	28.50	0.24 (0.04)	24	0.00	32.50	0.27 (0.04)	29	0.00	30.00	0.25 (0.06)
26	0.00	28.50	0.24 (0.04)	25	0.00	32.50	0.27 (0.04)	33	0.00	30.00	0.25 (0.06)
29	0.00	28.50	0.24 (0.04)	28	0.00	32.50	0.27 (0.04)	2	0.33	49.50	0.42 (3.14)
31	0.00	28.50	0.24 (0.04)	31	0.00	32.50	0.27 (0.04)	8	0.33	49.50	0.42 (3.14)
32	0.00	28.50	0.24 (0.04)	32	0.00	32.50	0.27 (0.04)	11	0.33	49.50	0.42 (3.14)
8	0.33	48.00	0.41 (3.12)	33	0.00	32.50	0.27 (0.04)	12	0.33	49.50	0.42 (3.14)
12	0.33	48.00	0.41 (3.12)	1	0.33	52.00	0.44 (3.13)	14	0.33	49.50	0.42 (3.14)
13	0.33	48.00	0.41 (3.12)	5	0.33	52.00	0.44 (3.13)	15	0.33	49.50	0.42 (3.14)
14	0.33	48.00	0.41 (3.12)	8	0.33	52.00	0.44 (3.13)	16	0.33	49.50	0.42 (3.14)
17	0.33	48.00	0.41 (3.12)	9	0.33	52.00	0.44 (3.13)	18	0.33	49.50	0.42 (3.14)
21	0.33	48.00	0.41 (3.12)	13	0.33	52.00	0.44 (3.13)	22	0.33	49.50	0.42 (3.14)
23	0.33	48.00	0.41 (3.12)	14	0.33	52.00	0.44 (3.13)	23	0.33	49.50	0.42 (3.14)
27	0.33	48.00	0.41 (3.12)	15	0.33	52.00	0.44 (3.13)	26	0.33	49.50	0.42 (3.14)
30	0.33	48.00	0.41 (3.12)	17	0.33	52.00	0.44 (3.13)	31	0.33	49.50	0.42 (3.14)
33	0.33	48.00	0.41 (3.12)	19	0.33	52.00	0.44 (3.13)	32	0.33	49.50	0.42 (3.14)
4	0.67	67.50	0.57 (3.12)	20	0.33	52.00	0.44 (3.13)	1	0.67	69.00	0.59 (3.14)
5	0.67	67.50	0.57 (3.12)	23	0.33	52.00	0.44 (3.13)	3	0.67	69.00	0.59 (3.14)
9	0.67	67.50	0.57 (3.12)	26	0.33	52.00	0.44 (3.13)	4	0.67	69.00	0.59 (3.14)
10	0.67	67.50	0.57 (3.12)	27	0.33	52.00	0.44 (3.13)	5	0.67	69.00	0.59 (3.14)
19	0.67	67.50	0.57 (3.12)	29	0.33	52.00	0.44 (3.13)	9	0.67	69.00	0.59 (3.14)
20	0.67	67.50	0.57 (3.12)	3	0.67	71.50	0.61 (3.13)	10	0.67	69.00	0.59 (3.14)
22	0.67	67.50	0.57 (3.12)	4	0.67	71.50	0.61 (3.13)	13	0.67	69.00	0.59 (3.14)
28	0.67	67.50	0.57 (3.12)	12	0.67	71.50	0.61 (3.13)	19	0.67	69.00	0.59 (3.14)
37	0.67	87.00	0.74 (0.04)	22	0.67	71.50	0.61 (3.13)	21	0.67	69.00	0.59 (3.14)
1	1.00	87.00	0.74 (0.04)	30	0.67	71.50	0.61 (3.13)	27	0.67	69.00	0.59 (3.14)
3	1.00	87.00	0.74 (0.04)	37	0.67	71.50	0.61 (3.13)	28	0.67	69.00	0.59 (3.14)
6	1.00	87.00	0.74 (0.04)	6	1.00	91.00	0.77 (0.04)	30	0.67	69.00	0.59 (3.14)
7	1.00	87.00	0.74 (0.04)	7	1.00	91.00	0.77 (0.04)	35	0.67	69.00	0.59 (3.14)
11	1.00	87.00	0.74 (0.04)	10	1.00	91.00	0.77 (0.04)	36	0.67	69.00	0.59 (3.14)
16	1.00	87.00	0.74 (0.04)	16	1.00	91.00	0.77 (0.04)	37	0.67	69.00	0.59 (3.14)
34	1.00	87.00	0.74 (0.04)	34	1.00	91.00	0.77 (0.04)	6	1.00	88.50	0.75 (0.06)
35	1.00	87.00	0.74 (0.04)	35	1.00	91.00	0.77 (0.04)	7	1.00	88.50	0.75 (0.06)
36	1.00	87.00	0.74 (0.04)	36	1.00	91.00	0.77 (0.04)	34	1.00	88.50	0.75 (0.06)
38	1.00	87.00	0.74 (0.04)	38	1.00	91.00	0.77 (0.04)	38	1.00	88.50	0.75 (0.06)
40	1.00	87.00	0.74 (0.04)	40	1.00	91.00	0.77 (0.04)	40	1.00	88.50	0.75 (0.06)

[1] *Numbers in parentheses are the standard error of the rank means (lower is better)*

Table 5: Color ratings for Princeton PGR trial

Mixture	Treatment	1WAT* Color Rating		4WAT* Color Rating		6WAT* Color Rating		8WAT* Color Rating		10WAT* Color Rating		12WAT Color Rating		15WAT Color Rating		17WAT Color Rating	
Stronghold	1	7.0	bc	7.0	b	6.7	bc	7.3	b-d	7.3	a-c	7.7	ab	7.7	a-c	7.0	a-c
	2	7.0	bc	4.0	e-g	6.0	b-e	7.0	b-e	6.7	b-d	7.3	ab	7.3	a-c	6.7	b-d
	3	7.3	ab	5.3	c-e	7.0	b	8.0	ab	7.0	b-d	7.0	b	8.0	ab	7.0	a-c
Stronghold + Telar	4	7.3	ab	3.7	fg	5.7	b-f	6.7	b-f	6.7	b-d	7.7	ab	7.0	bc	6.3	cd
	5	7.0	bc	3.7	fg	6.0	b-e	7.0	b-e	6.7	b-d	7.3	ab	6.7	c	6.3	cd
	6	7.0	bc	3.7	fg	4.3	e-h	6.7	b-f	7.3	a-c	7.3	ab	7.3	a-c	7.0	a-c
	7	7.0	bc	5.0	c-f	6.7	bc	6.7	b-f	6.7	b-d	7.3	ab	7.0	bc	6.7	b-d
	8	7.3	ab	4.7	c-g	5.0	c-h	6.0	d-h	6.3	c-e	7.0	b	7.0	bc	6.7	b-d
	9	7.0	bc	3.7	fg	5.3	b-g	6.0	d-h	6.3	c-e	8.0	a	7.3	a-c	6.3	cd
Stronghold + HiDep	10	6.7	c	5.0	c-f	6.0	b-e	7.0	b-e	7.0	b-d	7.3	ab	7.3	a-c	6.3	cd
	11	6.7	c	4.7	c-g	6.3	b-d	6.7	b-f	7.3	a-c	7.3	ab	8.0	ab	6.3	cd
	12	6.7	c	5.3	c-e	6.0	b-e	6.3	c-g	7.0	b-d	7.7	ab	7.0	bc	7.0	a-c
	13	6.0	d	4.7	c-g	6.7	bc	7.0	b-e	7.0	b-d	7.3	ab	7.3	a-c	6.7	b-d
	14	5.3	e	4.7	c-g	7.0	b	7.3	b-d	6.7	b-d	7.7	ab	6.7	c	6.7	b-d
	15	6.0	d	4.7	c-g	5.3	b-g	6.7	b-f	7.0	b-d	7.3	ab	7.0	bc	7.0	a-c
Stronghold + Escort	16	7.0	bc	4.0	e-g	4.7	d-h	6.7	b-f	7.0	b-d	8.0	a	7.7	a-c	7.0	a-c
	17	7.3	ab	3.7	fg	5.3	b-g	5.7	e-i	6.3	c-e	7.7	ab	7.0	bc	6.7	b-d
	18	7.0	bc	4.0	e-g	5.0	c-h	6.0	d-h	6.7	b-d	7.3	ab	7.3	a-c	6.7	b-d
	19	7.0	bc	4.7	c-g	3.7	gh	4.7	h-j	6.0	de	7.7	ab	7.3	a-c	6.7	b-d
	20	6.7	c	3.3	g	5.0	c-h	6.0	d-h	6.7	b-d	7.7	ab	7.3	a-c	6.0	d
	21	7.3	ab	4.7	c-g	4.0	f-h	4.0	j	5.3	e	7.0	b	7.0	bc	7.0	a-c
Plateau	22	7.0	bc	5.7	b-d	6.0	b-e	7.3	b-d	7.0	b-d	7.7	ab	7.0	bc	6.7	b-d
	23	7.0	bc	5.0	c-f	6.0	b-e	7.0	b-e	7.0	b-d	7.7	ab	7.3	a-c	6.7	b-d
	24	7.0	bc	3.7	fg	3.3	h	5.0	g-j	7.7	ab	7.7	ab	8.0	ab	6.7	b-d
	25	7.0	bc	4.7	c-g	5.7	b-f	5.7	e-i	6.7	b-d	7.0	b	7.0	bc	7.0	abc
Plateau + Escort	26	7.0	bc	4.7	c-g	5.3	b-g	6.7	b-f	6.3	c-e	7.7	ab	7.3	a-c	6.7	b-d
	27	7.3	ab	3.7	fg	4.3	e-h	5.0	g-j	7.0	b-d	7.0	b	7.3	a-c	7.0	a-c
	28	7.0	bc	4.0	e-g	4.3	e-h	4.0	j	5.3	e	7.3	ab	7.7	a-c	7.0	a-c
	29	7.0	bc	4.0	e-g	3.7	gh	4.3	i-j	6.0	de	7.3	ab	7.7	a-c	6.3	cd
	30	7.0	bc	6.0	bc	5.3	b-g	5.3	f-j	7.0	b-d	7.7	ab	8.0	ab	6.7	b-d
	31	6.7	c	3.7	fg	3.7	gh	4.7	h-j	6.3	c-e	8.0	a	7.7	a-c	6.7	b-d
	32	7.0	bc	3.3	g	3.3	h	4.3	ij	6.0	de	7.3	ab	7.7	a-c	7.0	a-c
	33	6.7	c	4.3	d-g	4.0	f-h	5.3	f-j	5.3	e	7.3	ab	7.3	a-c	6.0	d
Escort	34	7.0	bc	4.7	c-g	6.0	b-e	6.0	d-h	7.0	b-d	8.0	a	7.3	a-c	6.3	cd
	35	7.0	bc	5.0	c-f	7.0	b	7.3	b-d	7.7	ab	8.0	a	7.0	bc	6.7	b-d
	36	6.7	c	4.7	c-g	6.7	bc	7.3	b-d	7.0	b-d	8.0	a	7.7	a-c	7.0	a-c
RoundUp Pro	37	7.0	bc	5.0	c-f	6.7	bc	7.7	a-c	7.7	ab	7.7	ab	7.7	a-c	7.0	a-c
	38	7.0	bc	5.0	c-f	5.7	b-f	7.0	b-e	7.3	a-c	7.7	ab	7.3	a-c	7.3	ab
Untreated	40	7.7	a	9.0	a	9.0	a	9.0	a	8.3	a	8.0	a	8.3	a	7.7	a

Note: Treatment means followed by the same letter are not significantly different at p = 0.05 using Fisher's LSD.

Lexington PGR Trial Results

As previously stated, the timing of PGR applications is critical. The Lexington PGR applications were made approximately 3 weeks after the Princeton applications as full green up of tall fescue turf traditionally occurs later in central Kentucky than in western Kentucky. Unlike the Princeton PGR trial, only 2 treatments had prevented the growth of seedheads 1 WAT (Table 6). The presence of seedheads at 1WAT indicates that these seedhead were already formed at application but had yet to grow to be visible. This also indicates that the timing of the application was late. The ability of PGRs to inhibit the development of new seedheads after application is apparent in examining the 9 WAT height data as nine treatments had an average of 0 cm of seedhead growth at that time. These treatments included Stronghold tank mixtures (treatments 6,9,10,12), a Plateau treatment (treatment 22), and Plateau tank mixtures (treatments 26, 27, 31, 32).

There was an increase in the number of treatments that suppressed or reduced tall fescue seedheads from 4 WAT through 9 WAT (Table 7). This table is sorted by increasing rank means so as to show efficacy of treatments from best to worst. The number of treatments that had completely reduced the density of seedheads to 0 from 4 WAT to 9 WAT increased from one to nine. These data are concurrent with the data presented in Table 6. Treatments of RoundUp Pro and Escort alone were ineffective in preventing the development or reducing the density of tall fescue seedheads at 9 WAT which is similar to the results in the Princeton PGR trial. There is a general trend across all treatments of an increase in density reduction efficacy across time.

As with the Princeton PGR trial, seedhead data collected after 9-10 WAT were analyzed for presence or absence. No one treatment completely inhibited the development of tall fescue seedheads across the entire time of the trial. This is again due to the timing to the application. When examining the three data tables examining seedhead height (Table 6), seedhead density (Table 7), and seedhead presence (Table 8), there is considerable variation in the efficacy of all treatments.

Tall fescue vegetative color ratings at the Lexington PGR trial were considerably higher than those at the Princeton trial (Table 9). Color ratings at Lexington were never below the 5 level unlike the Princeton trial. This may be due to environmental conditions. The Princeton trial received approximately 5 inches of rain the month after application while the Lexington trial received approximately 9.5 inches of rain the month following application. Soil characteristics also varied between the two sites. The Princeton trial was located on a poorly drained soil with an argillic (clay) subsurface while the Lexington trial was located on a more fertile, well-drained loam. The differences in weather conditions between the two sites may have also influenced the results. Princeton weather data shows precipitation levels close to normal for the growing season while Lexington weather data shows precipitation levels to be well above normal for the entire growing season. This, as well as the timing of applications, may have caused the PGR applications at the Lexington sites to be less effective than those at the Princeton site.

There was no significant difference between treatments for broadleaf weed control. This is again due to the lack of considerable cover by broadleaf weeds. There was no treatment tested in the Lexington PGR trial that inhibited the seedhead growth of orchardgrass.

Future seedhead suppression research in 2005 will include Stronghold, Stronghold + Escort, Plateau, and Plateau + Escort Treatments.

Table 6: Adjusted mean seedhead height (cm) by treatment for Lexington PGR trial

Mixture	Treatment	1WAT		4WAT		6WAT		9WAT	
Stronghold	1	47.4	ab	73.4	a-c	75.7	a-d	58.5	a-d
	2	41	ab	48.7	a-e	33	b-e	23.3	b-d
	3	41.5	ab	33.6	a-e	33.2	b-e	19.7	c-d
Stronghold + Telar	4	24.3	ab	40.3	a-e	24.5	c-e	24.3	b-d
	5	35.6	ab	13.3	de	0	e	31.3	b-d
	6	0	b	30.5	c-e	28	c-e	0	d
	7	49	ab	55.6	a-e	50.3	a-e	56.8	a-d
	8	42.4	ab	60.1	a-d	21.7	de	54.8	a-d
	9	45.6	ab	48	a-e	0	e	0	d
Stronghold + HiDep	10	47.1	ab	51.6	a-e	0	e	0	d
	11	22.5	ab	27.5	c-e	45.3	a-e	54	a-d
	12	28.8	ab	38.5	a-e	46.7	a-e	0	d
	13	54.9	ab	48.2	a-e	38.4	b-e	32	b-d
	14	31	ab	0	e	29.5	b-e	41.5	a-d
	15	51.2	ab	51.9	a-e	55	a-e	47	a-d
Stronghold + Escort	16	50.7	ab	52.3	a-e	48.9	a-e	58.5	a-d
	17	32	ab	47.6	a-e	56.9	a-e	50.5	a-d
	18	33.3	ab	52.5	a-e	50.4	a-e	35	a-d
	19	54.9	ab	55.9	a-e	50.7	a-e	44.3	a-d
	20	45.7	ab	35.2	a-e	64.8	a-d	48	a-d
	21	18.7	ab	32.1	b-e	42	a-e	29.1	b-d
Plateau	22	50.7	ab	46.3	a-e	43.8	a-e	0	d
	23	61.7	ab	62.1	a-d	52.4	a-e	46	a-d
	24	47.8	ab	34.7	a-e	25.8	c-e	30	b-d
	25	53.8	ab	50	a-e	45.3	a-e	52.9	a-d
Plateau + Escort	26	0	b	40.1	a-e	38.6	a-e	0	d
	27	27.8	ab	36.7	a-e	0	e	0	d
	28	43.1	ab	58.1	a-d	53.9	a-e	54.6	a-d
	29	55.4	ab	53.6	a-e	51.2	a-e	54.3	a-d
	30	67.3	a	59.5	a-d	58.5	a-d	65.9	a-c
	31	35.2	ab	37.8	a-e	33.8	b-e	0	d
	32	51.3	ab	42.1	a-e	39.4	a-e	0	d
	33	30.6	ab	43.9	a-e	37.3	b-e	40.3	a-d
Escort	34	61.9	ab	89.7	ab	81.6	a-c	79.1	a-c
	35	42.5	ab	79.3	a-c	87.8	ab	84.5	ab
	36	42.4	ab	80.1	a-c	82.3	a-c	82.7	a-c
RoundUp Pro	37	49.3	ab	64.1	a-d	71.2	a-d	69.7	a-c
	38	25.3	ab	60.4	a-d	66.3	a-d	63.4	a-d
Untreated	40	66.1	a	91.3	a	98.3	a	96.1	a

Note: Treatment means followed by the same letter are not statistically different at p = 0.05 using Tukey-Kramer HSD

Table 7: Tall fescue seedhead density rank means by treatment for Lexington PGR

	4WAT				6WAT				9WAT		
Treatment	Ordinal Mean	Rank Mean	Treatment Effect[1]	Trt	Ordinal Mean	Rank Mean	Treatment Effect[1]	Trt	Ordinal Mean	Rank Mean	Treatment Effect[1]
14	0.00	17.50	0.15 (0.05)	5	0.00	25.50	0.21 (0.05)	6	0.00	30.00	0.25 (0.04)
5	0.33	30.17	0.26 (1.32)	9	0.00	25.50	0.21 (0.05)	9	0.00	30.00	0.25 (0.04)
6	0.33	30.17	0.26 (1.32)	10	0.00	25.50	0.21 (0.05)	10	0.00	30.00	0.25 (0.04)
11	0.33	30.17	0.26 (1.32)	27	0.00	25.50	0.21 (0.05)	12	0.00	30.00	0.25 (0.04)
20	0.33	30.17	0.26 (1.32)	2	0.33	38.83	0.33 (1.48)	22	0.00	30.00	0.25 (0.04)
21	0.33	30.17	0.26 (1.32)	3	0.33	38.83	0.33 (1.48)	26	0.00	30.00	0.25 (0.04)
26	0.67	40.00	0.34 (4.17)	4	0.33	38.83	0.33 (1.48)	27	0.00	30.00	0.25 (0.04)
32	0.67	40.00	0.34 (4.17)	6	0.33	38.83	0.33 (1.48)	31	0.00	30.00	0.25 (0.04)
2	0.67	42.83	0.36 (1.34)	8	0.33	38.83	0.33 (1.48)	32	0.00	30.00	0.25 (0.04)
3	0.67	42.83	0.36 (1.34)	13	0.33	38.83	0.33 (1.48)	25	1.00	34.67	0.55 (2.67)
4	0.67	42.83	0.36 (1.34)	14	0.33	38.83	0.33 (1.48)	2	0.33	44.33	0.37 (1.69)
9	0.67	42.83	0.36 (1.34)	24	0.33	38.83	0.33 (1.48)	3	0.33	44.33	0.37 (1.69)
12	0.67	42.83	0.36 (1.34)	31	0.33	38.83	0.33 (1.48)	4	0.33	44.33	0.37 (1.69)
22	0.67	42.83	0.36 (1.34)	32	0.67	46.17	0.39 (3.52)	5	0.33	44.33	0.37 (1.69)
24	0.67	42.83	0.36 (1.34)	25	1.00	49.83	0.42 (4.89)	13	0.33	44.33	0.37 (1.69)
27	0.67	42.83	0.36 (1.34)	26	1.00	49.83	0.42 (4.89)	18	0.33	44.33	0.37 (1.69)
31	0.67	42.83	0.36 (1.34)	11	0.67	52.17	0.44 (1.50)	21	0.33	44.33	0.37 (1.69)
33	0.67	42.83	0.36 (1.34)	18	0.67	52.17	0.44 (1.50)	23	0.33	44.33	0.37 (1.69)
1	1.33	47.83	0.41 (7.63)	21	0.67	52.17	0.44 (1.50)	24	0.33	44.33	0.37 (1.69)
23	1.00	52.67	0.45 (3.12)	22	0.67	52.17	0.44 (1.50)	15	0.67	50.33	0.43 (3.39)
25	1.00	52.67	0.45 (3.12)	33	0.67	52.17	0.44 (1.50)	1	1.33	56.50	0.48 (5.80)
7	1.00	55.50	0.47 (0.10)	12	1.00	59.50	0.50 (2.70)	8	0.67	58.67	0.50 (1.70)
10	1.00	55.50	0.47 (0.10)	23	1.00	59.50	0.50 (2.70)	11	0.67	58.67	0.50 (1.70)
13	1.67	60.50	0.52 (5.73)	29	1.00	59.50	0.50 (2.70)	14	0.67	58.67	0.50 (1.70)
30	1.33	62.50	0.53 (4.18)	15	1.33	63.17	0.54 (3.65)	20	0.67	58.67	0.50 (1.70)
8	1.33	65.33	0.55 (0.82)	28	1.33	63.17	0.54 (3.65)	33	0.67	58.67	0.50 (1.70)
18	1.33	65.33	0.55 (0.82)	20	1.00	65.50	0.56 (3.50)	17	1.00	64.67	0.55 (2.67)
29	1.33	65.33	0.55 (0.82)	16	1.33	66.83	0.57 (3.52)	28	1.00	64.67	0.55 (2.67)
15	1.67	66.33	0.56 (4.99)	19	1.33	66.83	0.57 (3.52)	19	1.67	70.83	0.60 (4.32)
28	1.67	69.17	0.59 (1.54)	30	1.33	66.83	0.57 (3.52)	30	1.67	73.17	0.62 (3.85)
19	2.00	85.00	0.72 (0.05)	1	1.67	67.00	0.57 (4.89)	7	1.33	79.00	0.67 (0.32)
16	2.33	88.83	0.76 (0.13)	7	1.67	80.17	0.68 (0.47)	29	2.00	85.17	0.72 (1.20)
17	2.33	88.83	0.76 (0.13)	17	2.00	83.83	0.71 (0.76)	16	2.00	91.00	0.77 (0.04)
38	4.00	100.50	0.85 (0.12)	38	2.67	94.83	0.81 (0.12)	38	3.00	98.50	0.84 (0.03)
34	4.00	108.50	0.92 (0.01)	37	3.67	106.17	0.90 (0.10)	37	3.33	102.17	0.87 (0.10)
35	4.00	108.50	0.92 (0.01)	34	4.00	110.00	0.94 (0.01)	34	4.00	109.50	0.93 (0.01)
36	4.00	108.50	0.92 (0.01)	35	4.00	110.00	0.94 (0.01)	35	4.00	109.50	0.93 (0.01)
37	4.00	108.50	0.92 (0.01)	36	4.00	110.00	0.94 (0.01)	36	4.00	109.50	0.93 (0.01)
40	4.00	108.50	0.92 (0.01)	40	4.00	110.00	0.94 (0.01)	40	4.00	109.50	0.93 (0.01)

[1] *Numbers in parentheses are the standard error of the rank means (lower is better)*

Table 8: Presence or absence of tall fescue seedheads by treatment at end of Lexington PRG trial

	12WAT				14WAT				18WAT		
Trt	Ordinal Mean	Rank Mean	Treatment Effect[1]	Trt	Ordinal Mean	Rank Mean	Treatment Effect[1]	Trt	Ordinal Mean	Rank Mean	Treatment Effect[1]
9	0.00	29.00	0.24 (0.07)	1	0.00	33.50	0.28 (0.04)	1	0.00	31.00	0.26 (0.06)
34	0.00	29.00	0.24 (0.07)	5	0.00	33.50	0.28 (0.04)	8	0.00	31.00	0.26 (0.06)
1	0.33	48.50	0.41 (3.15)	12	0.00	33.50	0.28 (0.04)	12	0.00	31.00	0.26 (0.06)
3	0.33	48.50	0.41 (3.15)	17	0.00	33.50	0.28 (0.04)	13	0.00	31.00	0.26 (0.06)
6	0.33	48.50	0.41 (3.15)	21	0.00	33.50	0.28 (0.04)	16	0.00	31.00	0.26 (0.06)
8	0.33	48.50	0.41 (3.15)	22	0.00	33.50	0.28 (0.04)	25	0.00	31.00	0.26 (0.06)
10	0.33	48.50	0.41 (3.15)	23	0.00	33.50	0.28 (0.04)	7	0.33	50.50	0.43 (3.14)
13	0.33	48.50	0.41 (3.15)	24	0.00	33.50	0.28 (0.04)	9	0.33	50.50	0.43 (3.14)
15	0.33	48.50	0.41 (3.15)	26	0.00	33.50	0.28 (0.04)	10	0.33	50.50	0.43 (3.14)
17	0.33	48.50	0.41 (3.15)	31	0.00	33.50	0.28 (0.04)	11	0.33	50.50	0.43 (3.14)
24	0.33	48.50	0.41 (3.15)	3	0.33	53.00	0.45 (3.13)	14	0.33	50.50	0.43 (3.14)
25	0.33	48.50	0.41 (3.15)	4	0.33	53.00	0.45 (3.13)	17	0.33	50.50	0.43 (3.14)
26	0.33	48.50	0.41 (3.15)	7	0.33	53.00	0.45 (3.13)	18	0.33	50.50	0.43 (3.14)
29	0.33	48.50	0.41 (3.15)	9	0.33	53.00	0.45 (3.13)	19	0.33	50.50	0.43 (3.14)
30	0.33	48.50	0.41 (3.15)	10	0.33	53.00	0.45 (3.13)	20	0.33	50.50	0.43 (3.14)
32	0.33	48.50	0.41 (3.15)	13	0.33	53.00	0.45 (3.13)	22	0.33	50.50	0.43 (3.14)
35	0.33	48.50	0.41 (3.15)	15	0.33	53.00	0.45 (3.13)	23	0.33	50.50	0.43 (3.14)
37	0.33	48.50	0.41 (3.15)	25	0.33	53.00	0.45 (3.13)	26	0.33	50.50	0.43 (3.14)
38	0.33	48.50	0.41 (3.15)	28	0.33	53.00	0.45 (3.13)	27	0.33	50.50	0.43 (3.14)
2	0.67	68.00	0.58 (3.15)	29	0.33	53.00	0.45 (3.13)	29	0.33	50.50	0.43 (3.14)
5	0.67	68.00	0.58 (3.15)	30	0.33	53.00	0.45 (3.13)	30	0.33	50.50	0.43 (3.14)
7	0.67	68.00	0.58 (3.15)	32	0.33	53.00	0.45 (3.13)	31	0.33	50.50	0.43 (3.14)
11	0.67	68.00	0.58 (3.15)	33	0.33	53.00	0.45 (3.13)	33	0.33	50.50	0.43 (3.14)
12	0.67	68.00	0.58 (3.15)	38	0.33	53.00	0.45 (3.13)	2	0.67	70.00	0.59 (3.14)
14	0.67	68.00	0.58 (3.15)	2	0.67	72.50	0.62 (3.13)	3	0.67	70.00	0.59 (3.14)
16	0.67	68.00	0.58 (3.15)	11	0.67	72.50	0.62 (3.13)	4	0.67	70.00	0.59 (3.14)
18	0.67	68.00	0.58 (3.15)	16	0.67	72.50	0.62 (3.13)	6	0.67	70.00	0.59 (3.14)
19	0.67	68.00	0.58 (3.15)	18	0.67	72.50	0.62 (3.13)	15	0.67	70.00	0.59 (3.14)
20	0.67	68.00	0.58 (3.15)	19	0.67	72.50	0.62 (3.13)	21	0.67	70.00	0.59 (3.14)
21	0.67	68.00	0.58 (3.15)	20	0.67	72.50	0.62 (3.13)	24	0.67	70.00	0.59 (3.14)
31	0.67	68.00	0.58 (3.15)	36	0.67	72.50	0.62 (3.13)	28	0.67	70.00	0.59 (3.14)
33	0.67	68.00	0.58 (3.15)	37	0.67	72.50	0.62 (3.13)	32	0.67	70.00	0.59 (3.14)
4	1.00	87.50	0.74 (0.07)	6	1.00	92.00	0.78 (0.05)	5	1.00	89.50	0.76 (0.06)
22	1.00	87.50	0.74 (0.07)	8	1.00	92.00	0.78 (0.05)	34	1.00	89.50	0.76 (0.06)
23	1.00	87.50	0.74 (0.07)	14	1.00	92.00	0.78 (0.05)	35	1.00	89.50	0.76 (0.06)
27	1.00	87.50	0.74 (0.07)	27	1.00	92.00	0.78 (0.05)	36	1.00	89.50	0.76 (0.06)
28	1.00	87.50	0.74 (0.07)	34	1.00	92.00	0.78 (0.04)	37	1.00	89.50	0.76 (0.06)
36	1.00	87.50	0.74 (0.07)	35	1.00	92.00	0.78 (0.04)	38	1.00	89.50	0.76 (0.06)
40	1.00	87.50	0.74 (0.07)	40	1.00	92.00	0.78 (0.04)	40	1.00	89.50	0.76 (0.06)

[1] *Numbers in parentheses are the standard error of the rank means (lower is better)*

Table 9: Color ratings for Lexington PGR trial

Mixture	Treatment	1WAT Color Rating		4WAT* Color Rating		6WAT* Color Rating		9WAT* Color Rating		12WAT Color Rating		14WAT* Color Rating		18WAT Color Rating	
Stronghold	1	8	a	7.3	cde	6.7	bcd	8	a	7.7	ab	7.3	bcd	7.7	ab
	2	8	a	7	def	6.7	bcd	7.3	abc	7	bc	7	cd	7.3	b
	3	8	a	7	def	6.3	cde	7	cb	7	bc	7.3	bcd	7.3	b
Stronghold + Telar	4	8	a	7	def	7	bc	7	cb	7	bc	8	ab	7.7	ab
	5	8	a	6.7	efg	6.3	cde	7	cb	7.7	ab	7	cd	7	b
	6	8	a	7	def	6.7	bcd	7.7	ab	7.7	a	7.3	bcd	7	b
	7	8	a	7	def	7	bc	7	cb	7.3	abc	7.3	bcd	7	b
	8	7.7	a	7.7	cd	7	bc	7	cb	7.7	ab	7	cd	7.7	ab
	9	7.7	a	7	def	6.3	cde	7.7	ab	7.3	abc	7	cd	7.7	ab
Stronghold + HiDep	10	8	a	7	def	6.7	bcd	7	cb	6.7	c	7.3	bcd	7.7	ab
	11	7.7	a	8	bc	7.3	b	7.3	abc	7	bc	7.3	bcd	7.3	b
	12	8	a	7.7	cd	6.7	bcd	7	cb	7	bc	7	cd	7	b
	13	8	a	7	def	7.3	b	7.3	abc	7	bc	7	cd	7	b
	14	8	a	7	def	7	bc	7.3	abc	7	bc	6.7	d	7.7	ab
	15	7.7	a	7	def	6.7	bcd	7	cb	7	bc	7	cd	7.3	b
Stronghold + Escort	16	8	a	7.3	cde	6.7	bcd	7	cb	7.3	abc	7.3	bcd	7.3	b
	17	8	a	7.3	cde	7	bc	8	a	6.7	c	7.3	bcd	7.3	b
	18	7.7	a	7	def	6.7	bcd	7	cb	7.3	abc	7	cd	7	b
	19	7.7	a	7	def	6.7	bcd	7.3	abc	7.7	ab	7	cd	7.7	ab
	20	7.7	a	6	g	5.3	fg	6.7	c	7.3	abc	7.7	abc	7.3	b
	21	7.7	a	7	def	6.3	cde	7.3	abc	7.7	ab	6.7	d	7.7	ab
Plateau	22	8	a	7	def	6	def	7.3	abc	7.3	abc	7.7	abc	7.3	b
	23	7.7	a	7.3	cde	5.7	efg	7.7	ab	7	bc	7.3	bcd	7	b
	24	7.7	a	6.7	efg	5.3	fg	7	cb	7.3	abc	7.3	bcd	7	b
	25	8	a	7	def	5	g	7.3	abc	8		8	ab	7.3	b
Plateau + Escort	26	8	a	7	def	6.3	cde	7.7	ab	7.3	abc	7.3	bcd	7.3	b
	27	8	a	7	def	6	def	7.3	abc	7	bc	7	cd	7	b
	28	7.7	a	7	def	5	g	7.7	ab	7.7	ab	7.7	abc	7.3	b
	29	8	a	6.7	efg	5	g	7.3	abc	7.7	ab	8	ab	7.3	b
	30	8	a	7	def	6.3	cde	7.3	abc	7	bc	7	cd	7	b
	31	7.7	a	6.3	fg	5.7	efg	7.7	ab	7.3	abc	7.3	bcd	7	b
	32	7.7	a	6.7	efg	5.3	fg	7.3	abc	7.7	ab	7.3	bcd	7.7	ab
	33	7.7	a	7	def	5	g	7	cb	7.7	ab	7.7	abc	7.3	b
Escort	34	8	a	8.7	ab	8.3	a	7.7	ab	7.3	abc	7.7	abc	7.7	ab
	35	7.7	a	8.7	ab	9	a	8	a	7.3	abc	8	ab	8.3	a
	36	8	a	9	a	8.3	a	8	a	6.7	c	8	ab	7.7	ab
RoundUp Pro	37	8	a	7.3	cde	6.7	bcd	7	cb	7.3	abc	7.7	abc	7.3	b
	38	7.7	a	6.7	efg	6.7	bcd	7	cb	7	bc	7	cd	7	b
Untreated	40	8	a	9	a	9	a	8	a	8	a	8.3	a	7.7	ab

Note: Treatment means followed by the same letter are not significantly different at p = 0.05 using Fisher's LSD.