Flight 93 National Memorial Reforestation Project (Phases I-IV)

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Photo credit: National Park Service

Field collection

Photo: *Ian Forte (left) and Cassandra Krul (right) collecting field data at Flight 93 National Memorial. Posted 09.08.15 at http://www.iup.edu/news-item.aspx?id=201760*

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Green Forests Work

The National Park Foundation (Permit #: FLNI-2015-SCI-0003)

Indiana University of Pennsylvania, Department of Biology

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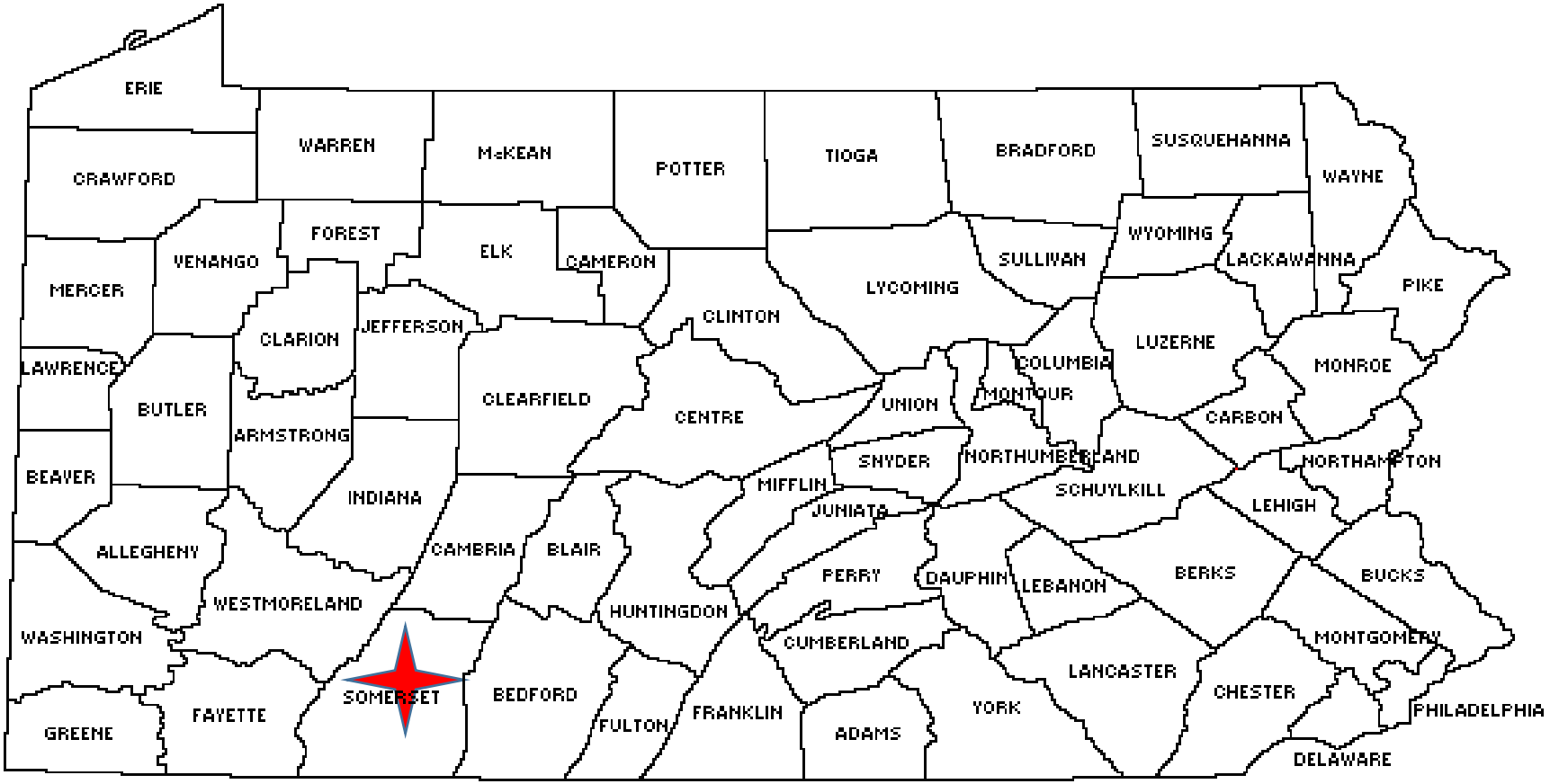
Flight 93 National Memorial



Near Shanksville, PA
(40.058, -78.905)

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Flight 93 National Memorial

September 10, 2011

The site was officially dedicated and opened to the public

Photo credit: National Park Foundation. Accessed on 04.06.17 at http://www.honorflight93.org/remember/?fa=dedication

Flight 93 National Memorial

1950's until mid-1990's
Surface mined and then most of the 890 ha of was re-contoured and seeded.

Flight 93 National Memorial

2012 - today

National Park Service &
Office of Surface Mining
Reclamation and Enforcement teamed
with others to begin reforesting sections
using native woody trees and shrubs

Photo credit: National Park Service

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Reforestation Project (2012-15; Phases I-IV)

Phase	Year	Area ha (ac)	No. of trees
I	2012	7.7 (19)	14,369
II	2013	9.1 (23)	17,300
III	2014	11.3 (28)	20,550
IV	2015	11.2 (28)	22,000
Total		**39.3 (98)**	**74,219**

> 30 spp. of native trees and shrubs

Planting List

Plant name	Phase I (2012) # plants	Phase I (2012) #/ha	Phase II (2013) # plants	Phase II (2013) #/ha	Phase III (2014) # plants	Phase III (2014) #/ha	Phase IV (2015) # plants	Phase IV (2015) #/ha	Total (All) # plants
white pine	4,600	599	6,700	734	8,200	728	9,050	810	**28,550**
red pine	700	91	200	22	200	18	200	18	**1,300**
pitch pine	500	65	500	55	600	53	0	0	**1,600**
Virginia pine	0	0	0	0	0	0	350	31	**350**
eastern hemlock	0	0	1,200	131	800	71	700	63	**2,700**
red spruce	0	0	0	0	800	71	700	63	**1,500**
Conifer tree species subtotal	***5,800***	***755***	***8,600***	***942***	***10,600***	***941***	***11,000***	***984***	***36,000***
red oak	1,200	156	2,000	219	2,000	178	2,400	215	**7,600**
white oak	600	78	600	66	800	71	1,100	98	**3,100**
black oak	600	78	0	0	0	0	0	0	**600**
sugar maple	800	104	970	106	600	53	700	63	**3,070**
red maple	600	78	300	33	200	18	200	18	**1,300**
black cherry	600	78	800	88	1,000	89	500	45	**2,900**
black locust	600	78	800	88	900	80	900	81	**3,200**
quaking aspen	500	65	600	66	800	71	900	81	**2,800**
black walnut	100	13	200	22	400	36	400	36	**1,100**
blackgum	400	52	0	0	0	0	0	0	**400**
yellow-poplar	0	0	200	22	200	18	200	18	**600**
hickory species	0	0	0	0	500	44	1,100	98	**1,600**
American elm	0	0	150	16	150	13	0	0	**300**
American chestnut backcrosses	*569	74	480	53	1,000	89	1,500	134	**3,549**
Deciduous tree species subtotal	***6,569***	***855***	***7,100***	***778***	***8,550***	***759***	***9,900***	***886***	***32,119***
American hazelnut	0	0	0	0	100	9	0	0	**100**
flowering dogwood	400	52	200	22	0	0	200	18	**800**
gray dogwood	300	39	200	22	0	0	0	0	**500**
silky dogwood	300	39	200	22	300	27	0	0	**800**
red osier dogwood	0	0	200	22	500	44	500	45	**1,200**
sweet American crabapple	300	39	200	22	0	0	200	18	**700**
Washington hawthorn	300	39	200	22	0	0	0	0	**500**
elderberry	200	26	200	22	0	0	0	0	**400**
staghorn sumac	100	13	0	0	0	0	0	0	**100**
mountain ash	100	13	0	0	0	0	200	18	**300**
ninebark	0	0	200	22	0	0	0	0	**200**
scrub oak	0	0	0	0	500	44	0	0	**500**
Wildlife trees & shrubs subtotal	***2,000***	***260***	***1,600***	***175***	***1,400***	***124***	***1,100***	***98***	***6,100***
GRAND TOTAL	**14,369**	**1,869**	**17,300**	**1,895**	**20,550**	**1,824**	**22,000**	**1,968**	**74,219**

***Table**. Absolute (total number) and relative (plants per hectare) abundance of woody trees and shrubs planted across the Phases I-IV of The Flight 93 National Monument Reforestation Project. Planting for each phase took place in the second half of April of each year.*

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Reforestation Project (2012-15; Phases I-IV)

Objectives

1. *Survival*
2. *Deer Browse*
3. *Competing Vegetation*
4. *Planting Position*

Summer 2015 each Phase was evaluated independently and represented 3, 2, 1, and 0.25 years following planting of Phase I, II, III, and IV, respectively.

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Reforestation Project (2012; Phase I)

Size = 7.7 ha (19 ac)
No. of plots = 28
Percent sampling = 15%

Reforestation Project (2013; Phase II)

Size = 9.1 ha (23 ac)
No. of plots = 30
Percent sampling = 13%

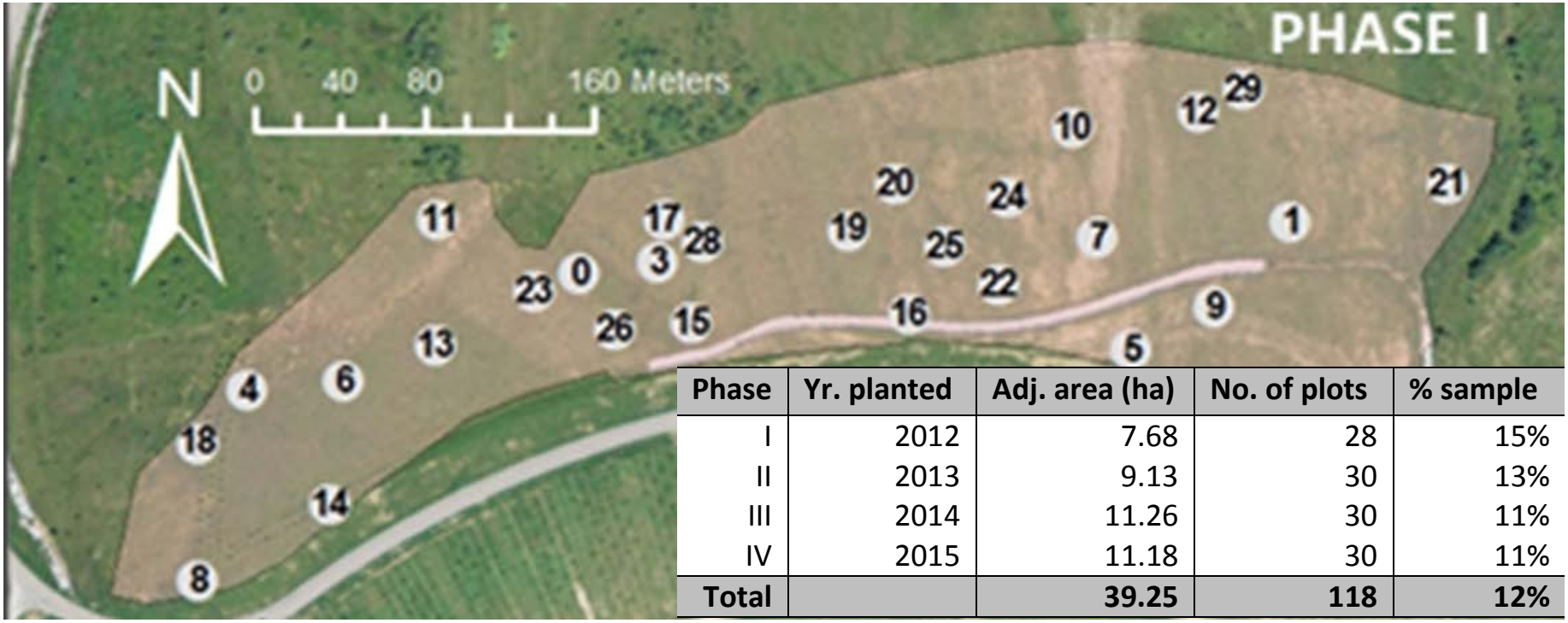
Reforestation Project (2014; Phase III)

Size = 11.3 ha (28 ac)
No. of plots = 30
Percent sampling = 11%

Reforestation Project (2015; Phase IV)

Size = 11.2 ha (28 ac)
No. of plots = 30
Percent sampling = 11%

Plot Establishment



Phase	Yr. planted	Adj. area (ha)	No. of plots	% sample
I	2012	7.68	28	15%
II	2013	9.13	30	13%
III	2014	11.26	30	11%
IV	2015	11.18	30	11%
Total		**39.25**	**118**	**12%**

Step 1: *Plot boundary captured using Garmin 64s handheld GPS*

Step 2: *Random plot centers generated using ArcGIS 10.2*

Constraints

> 30 meters between plot centers

> 5 meters from boundary edge

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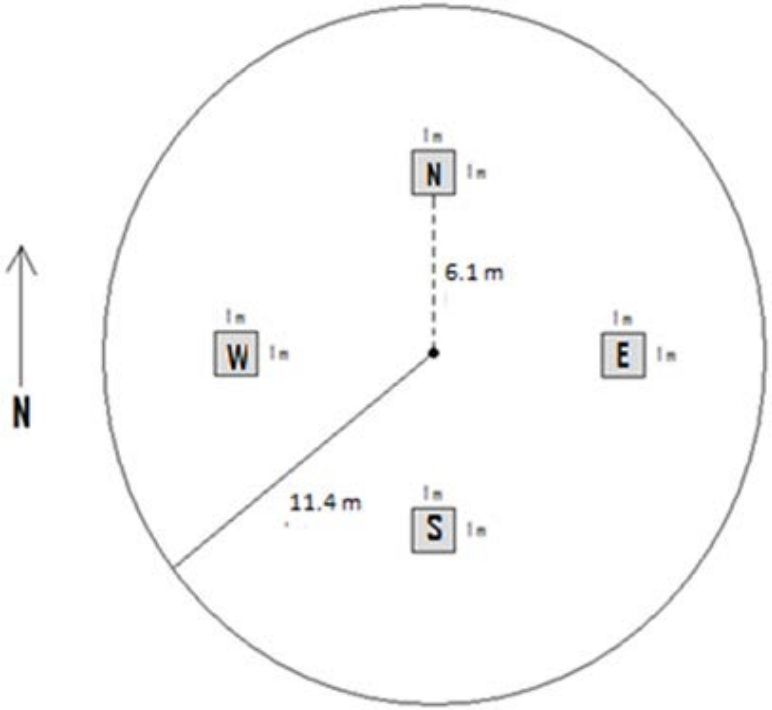
Plot Establishment



Plot layout with 0.04 ha (0.10 ac) survey plot with four 1 m² nested sub-plots for percent cover determination.

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Whole-Plot Measurements

All "planted" woody plants within plot boundary were measured

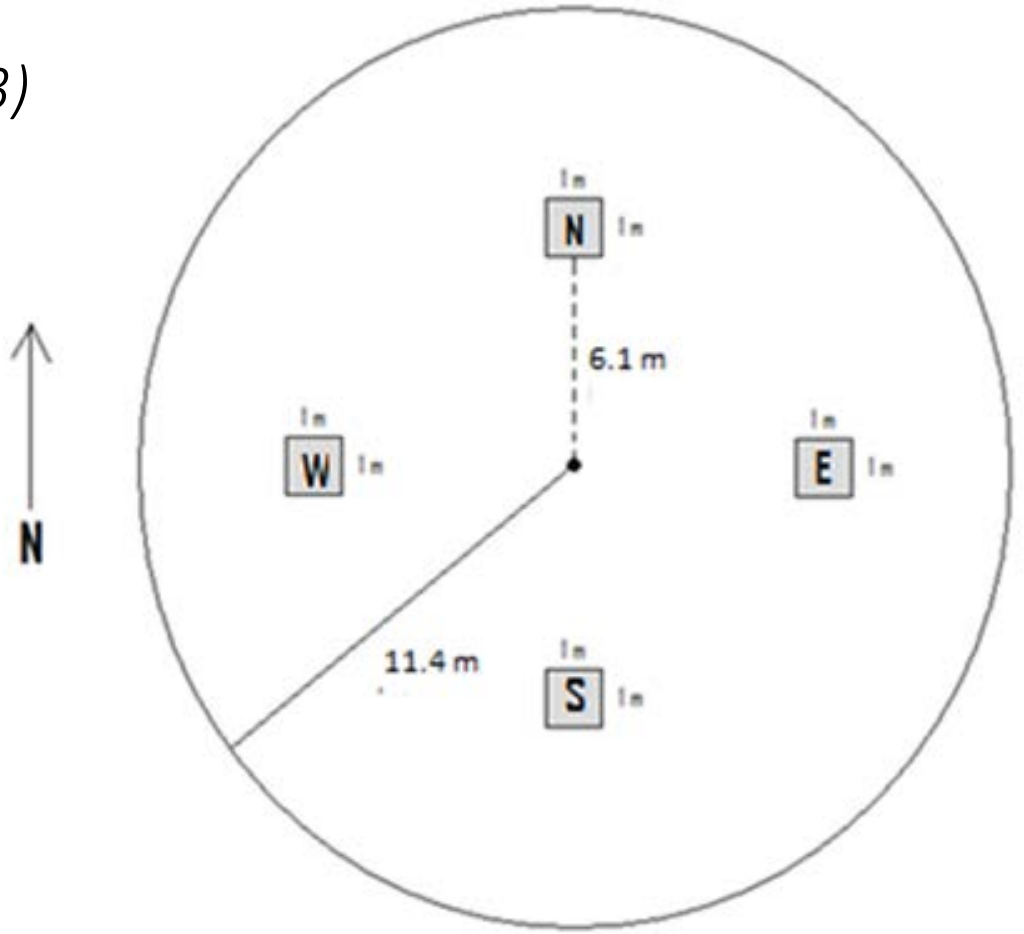
Measurements (Obj.)	
Height	*(Obj. 1)*
Basal diameter	*(Obj. 1)*
Species	*(Obj. 1)*
Vigor index	*(Obj. 1)*
Browse index	*(Obj. 2)*
Planting position	*(Obj. 4)*

Image: Posted 09.08.15 at http://www.iup.edu/news-item.aspx?id=201760

Nested Sub-Plot Measurements

Competing vegetation (Obj. 3)

Categories (nearest 5%)
Bare soil
Rock
Woody debris
Grass/sedge
Fern
Forb
Rubus spp.
Woody vegetation
Other
Totaled 100%



Data Analysis

Phases were treated as a separate experiments

Plot-level variables that were calculated for each species (Table)

Variable	Description	Symbol	Units
Species Abundance	Number of individual plants for each species found within the phase	*n*	# or no.
Relative abundance (observed)	Number of plants relativized by plot size (0.04 ha) and expressed on an area basis	plants/ha	#/ha
Mean height	Mean height of all plants for each species within the plot	Avg HT	cm
Minimum height	Shortest individual for each species within the plot	Min	cm
Maximum height	Tallest individual for each species within the plot	Max	cm
Mean diameter	Mean basal diameter of al plants for each species within the plot	Avg DIA	mm
Mean vigor	Mean vigor value for each species within the plot.	Vigor	index
Percent BO	Percentage of plants that show no sign of deer browse	% B0	%
Percent B1	Percentage of plants with light deer browse	% B1	%
Percent B2	Percentage of plants with moderate deer browse	% B2	%
Percent B3	Percentage of plants with heavy deer browse	% B3	%

Phase-level data was averaged and standard error calculated.

Treatments (position) were tested using ANOVA
PDIFF Option for mean separation.

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Overall Survival

A total of 74,069 trees were planted across phases I-IV

Overall survival was 55%

Range was 93% - 37% within individual phases

Phase I (2012)	93% (adj. 75%)
Phase II (2013)	54%
Phase III (2014)	41%
Phase IV (2015)	37%

Phase I Survival (Obj. 1) *[3 yrs.]*

	PHASE I: Survival	Planted	Observed ± se	Diff.	Survival	Distrib.	Tot. Plants ± se
	Plant name	*(#/ha)*	*(#/ha)*	*(+/-)*	*(%)*	*(# plots)*	*(#/phase)*
+	white pine	599	380 ± 2.0	-219	63	26	2,920 ± 15.5
	red pine	91	20 ± 0.1	-71	22	17	152 ± 1.1
+	pitch pine	65	43 ± 0.3	-22	66	21	331 ± 2.2
	Virginia pine	0	-	-	-	-	-
	eastern hemlock	0	-	-	-	-	-
	red spruce	0	-	-	-	-	-
	Conifer tree subtotal	**755**	**443**	**-312**	**59**	**-**	**3,403**
+	red oak	156	131 ± 0.8	-25	84	23	1,006 ± 5.9
+	white oak	78	52 ± 0.3	-26	67	21	397 ± 2.6
	black oak	78	34 ± 0.3	-44	44	17	258 ± 2.3
	sugar maple	104	47 ± 0.3	-57	45	21	358 ± 2.6
?	red maple	**78**	**115 ± 1.4**	**+37**	**147**	**19**	**881 ± 11.1**
	black cherry	78	68 ± 0.4	-10	87	23	523 ± 3.0
?	black locust	78	78 ± 0.4	0	100	24	602 ± 3.2
	quaking aspen	65	38 ± 0.3	-27	58	17	291 ± 2.4
	black walnut	13	0	-13	0	0	0
	blackgum	52	46 ± 0.7	-6	88	8	351 ± 5.5
	yellow-poplar	0	-	-	-	-	-
	hickory species	0	-	-	-	-	-
	American elm	0	-	-	-	-	-
-	American chestnut backcross	74	28 ± 0.3	-46	38	16	212 ± 2.0
	Deciduous tree subtotal	**854**	**637**	**-217**	**75**	**-**	**4,879**

*

93% (adj. 75%)

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Phase II Survival (Obj. 1) *[2 yrs.]*

	PHASE II: Survival	Planted	Observed ± se	Diff.	Survival *	Distrib.	Tot. Plants ± se
	Plant name	***(#/ha)***	***(#/ha)***	***(+/-)***	***(%)***	***(# plots)***	***(#/phase)***
+	white pine	734	434 ± 2.1	-300	59	29	3964 ± 18.7
	red pine	22	3 ± 0.1	-19	11	3	23 ± 0.5
+	pitch pine	55	48 ± 0.4	-7	87	15	434 ± 4.1
	Virginia pine	0	-	-	-	-	-
-	eastern hemlock	131	53 ± 0.5	-79	40	13	479 ± 4.9
	red spruce	0	-	-	-	-	-
	Conifer tree subtotal	***942***	***537***	***-405***	***57***	***-***	***4,900***
	red oak	219	102 ± 0.4	-117	46	30	928 ± 3.9
	white oak	66	25 ± 0.2	-41	38	20	228 ± 1.5
	black oak	0	**1 ± 0.0**	**+1**	-	1	8 ± 0.3
	sugar maple	106	57 ± 0.4	-50	53	23	517 ± 3.4
	red maple	33	13 ± 1.4	-20	38	10	114 ± 1.4
+	black cherry	88	74 ± 0.4	-13	85	26	677 ± 3.3
	black locust	88	36 ± 0.3	-52	41	18	327 ± 3.0
+	quaking aspen	66	46 ± 0.3	-20	70	24	418 ± 2.4
	black walnut	22	18 ± 0.3	-4	84	9	167 ± 2.7
	blackgum	0	-	-	-	-	-
	yellow-poplar	22	7 ± 0.1	-15	30	5	61 ± 1.1
	hickory species	0	-	-	-	-	-
	American elm	16	0	-16	0	0	0
+	American chestnut backcross	53	38 ± 0.2	-15	71	25	342 ± 2.2
	Deciduous tree subtotal	***778***	***415***	***-363***	***53***	***-***	***3,789***

54%

Phase III Survival (Obj. 1) *[1 yrs.]*

	PHASE III: Survival	Planted	Observed ± se	Diff.	Survival	Distrib.	Tot. Plants ± se
	Plant name	***(#/ha)***	***(#/ha)***	***(+/-)***	***(%)***	***(# plots)***	***(#/phase)***
+	white pine	728	382 ± 1.8	-346	52	29	4298 ± 19.8
	red pine	18	2 ± 0.0	-16	9	2	19 ± 0.5
	pitch pine	53	14 ± 0.3	-39	27	6	160 ± 3.6
	Virginia pine	0	-	-	-	-	-
-	eastern hemlock	71	14 ± 0.2	-57	20	8	160 ± 2.7
-	red spruce	71	8 ± 0.2	-63	12	3	94 ± 2.7
	Conifer tree subtotal	**941**	**420**	**-521**	**45**		**4,729**
	red oak	178	74 ± 0.5	-104	42	25	835 ± 5.8
-	white oak	71	7 ± 0.1	-64	9	7	75 ± 1.1
	black oak	**0**	**4 ± 0.1**	**4**	**-**	**4**	**47 ± 0.9**
	sugar maple	53	22 ± 0.2	-31	41	16	244 ± 2.2
	red maple	18	8 ± 0.1	-10	46	9	94 ± 1.1
+	black cherry	89	42 ± 0.3	-47	47	22	469 ± 3.3
+	black locust	80	41 ± 0.2	-39	51	22	460 ± 2.8
+	quaking aspen	71	33 ± 0.2	-39	46	20	366 ± 2.8
	black walnut	36	1 ± 0.0	-35	2	1	9 ± 0.4
	blackgum	0	-	-	-	-	-
	yellow-poplar	18	6 ± 0.1	-12	32	6	66 ± 1.0
	hickory species	44	11 ± 0.2	-33	25	9	122 ± 1.8
	American elm	13	-	-	-	-	-
	American chestnut backcross	89	34 ± 0.4	-55	38	14	385 ± 4.2
	Deciduous tree subtotal	**747**	**282**	**-464**	**38**		**3,172**

41%

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Phase IV Survival (Obj. 1) *[3 mo.]*

	PHASE IV: Survival	Planted	Observed ± se	Diff.	Survival	Distrib.	Tot. Plants ± se
	Plant name	***(#/ha)***	***(#/ha)***	***(+/-)***	***(%)***	***(# plots)***	***(#/phase)***
	white pine	810	288 ± 1.2	-522	36	26	3224 ± 13.1
	red pine	18	0	-18	0	0	0
	pitch pine	**0**	**1 ± 0.0**	**1**	*	**1**	**9 ± 0.4**
+	Virginia pine	31	25 ± 0.2	-6	81	16	280 ± 2.8
-	eastern hemlock	63	15 ± 0.2	-48	24	8	168 ± 2.6
	red spruce	63	22 ± 0.9	-41	34	1	242 ± 9.7
	Conifer tree subtotal	**984**	**351**	**-633**	**36**	**36**	**3,922**
	red oak	215	90 ± 0.5	-125	42	26	1006 ± 5.6
	white oak	98	45 ± 0.3	-53	46	20	503 ± 3.7
	black oak	0	-	-	-	-	-
	sugar maple	63	26 ± 0.2	-37	41	21	289 ± 2.2
	red maple	18	8 ± 0.1	-11	42	8	84 ± 1.1
+	black cherry	45	33 ± 0.3	-13	72	16	363 ± 3.3
	black locust	81	18 ± 0.2	-63	23	10	205 ± 2.7
	quaking aspen	81	42 ± 1.0	-39	51	3	466 ± 10.9
	black walnut	36	22 ± 0.3	-14	60	10	242 ± 3.4
	blackgum	0	-	-	-	-	-
	yellow-poplar	18	6 ± 0.1	-12	32	4	65 ± 1.4
	hickory species	98	3 ± 0.1	-96	3	2	28 ± 0.8
	American elm	0	-	-	-	-	-
*	American chestnut backcross	134	57 ± 0.4	-77	42	23	634 ± 4.3
	Deciduous tree subtotal	**886**	**348**	**-539**	**39**	**39**	**3,885**

37%

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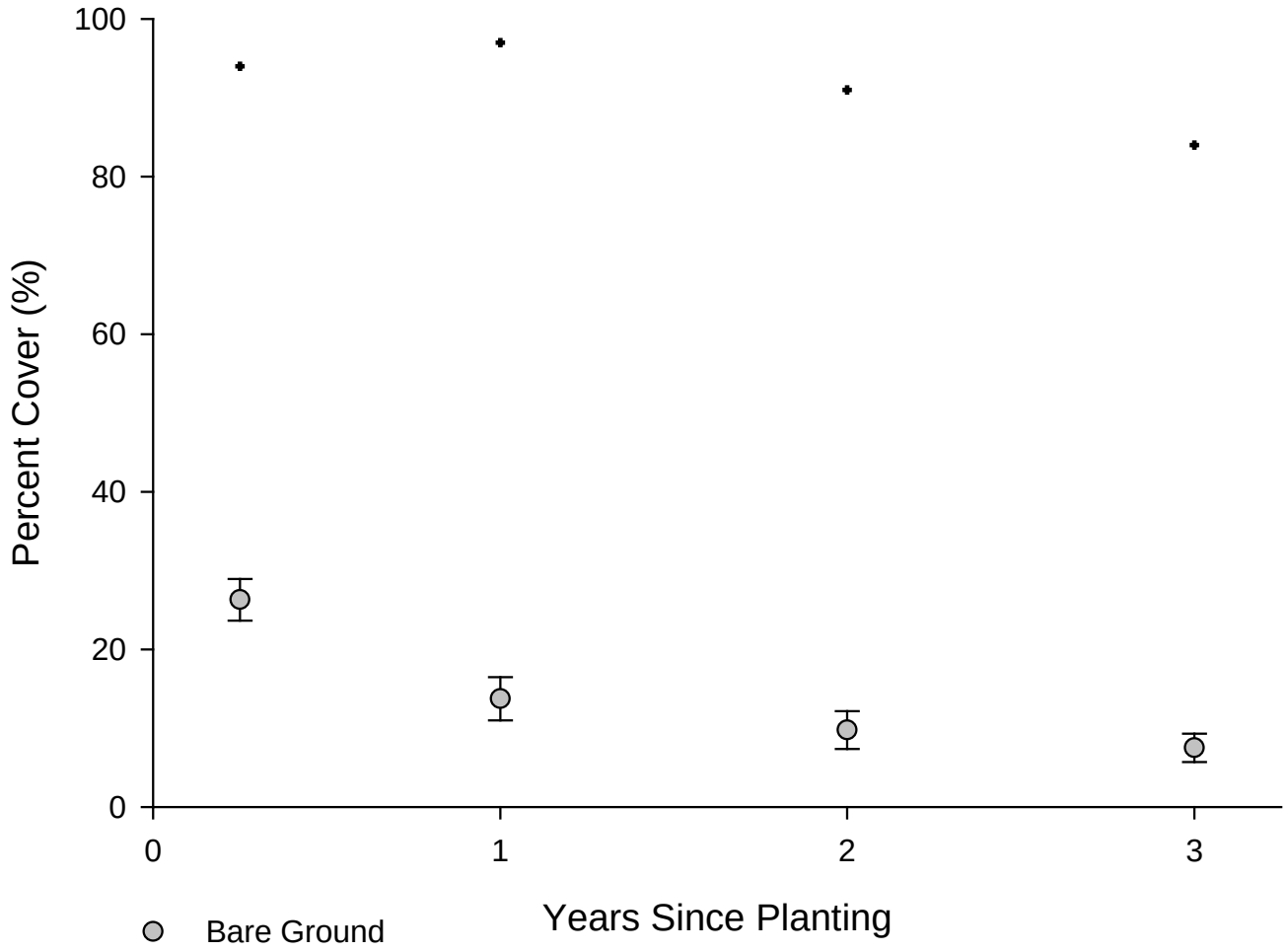
Deer Browse (Obj. 2)

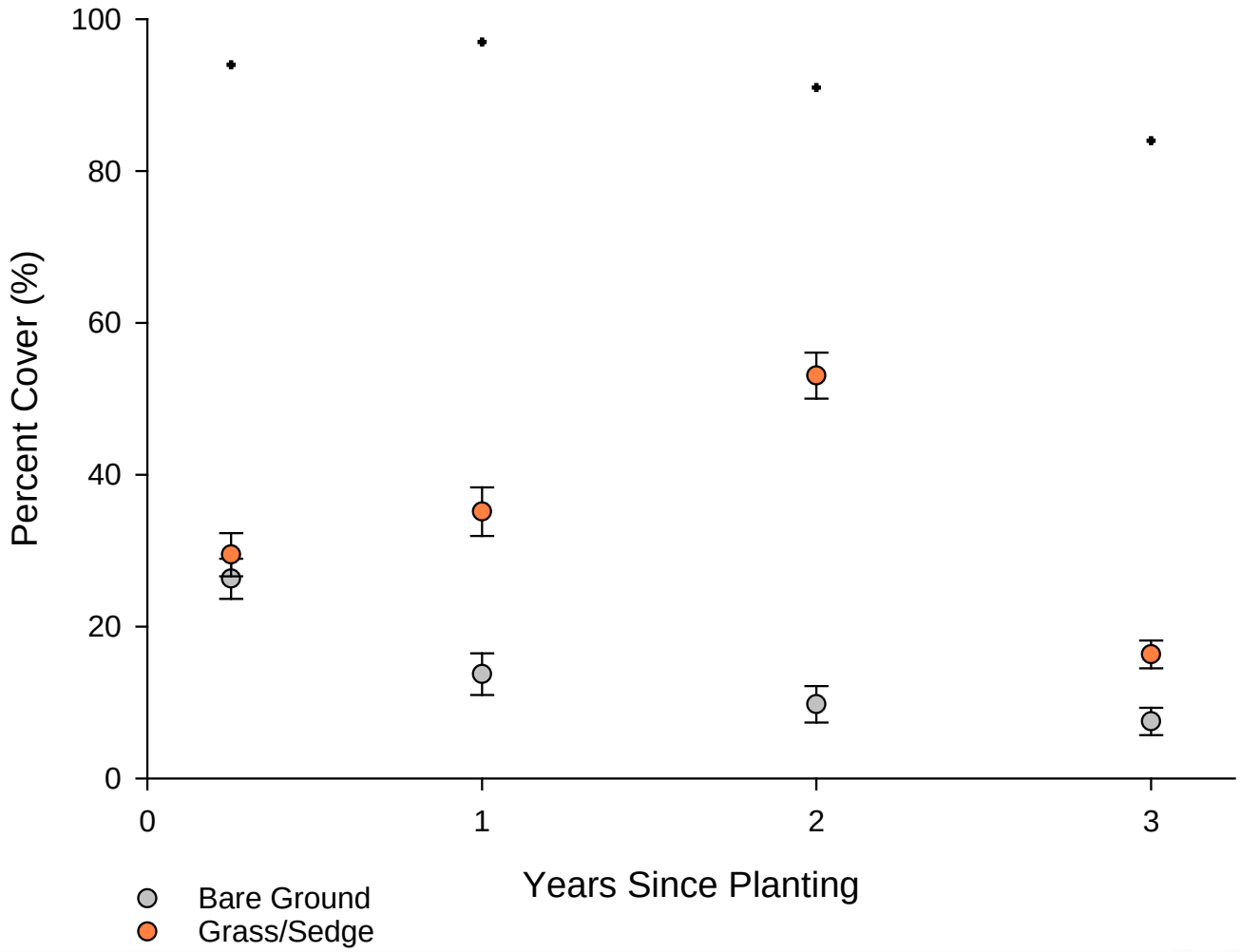
- Deer browse was extremely low across all four phases (3%)
- Phase I showed the greatest with 5%
- Quaking aspen (19%) and blackgum (18%) showed highest level.

Caution, Caution, Caution, Caution, Caution, Caution, Caution

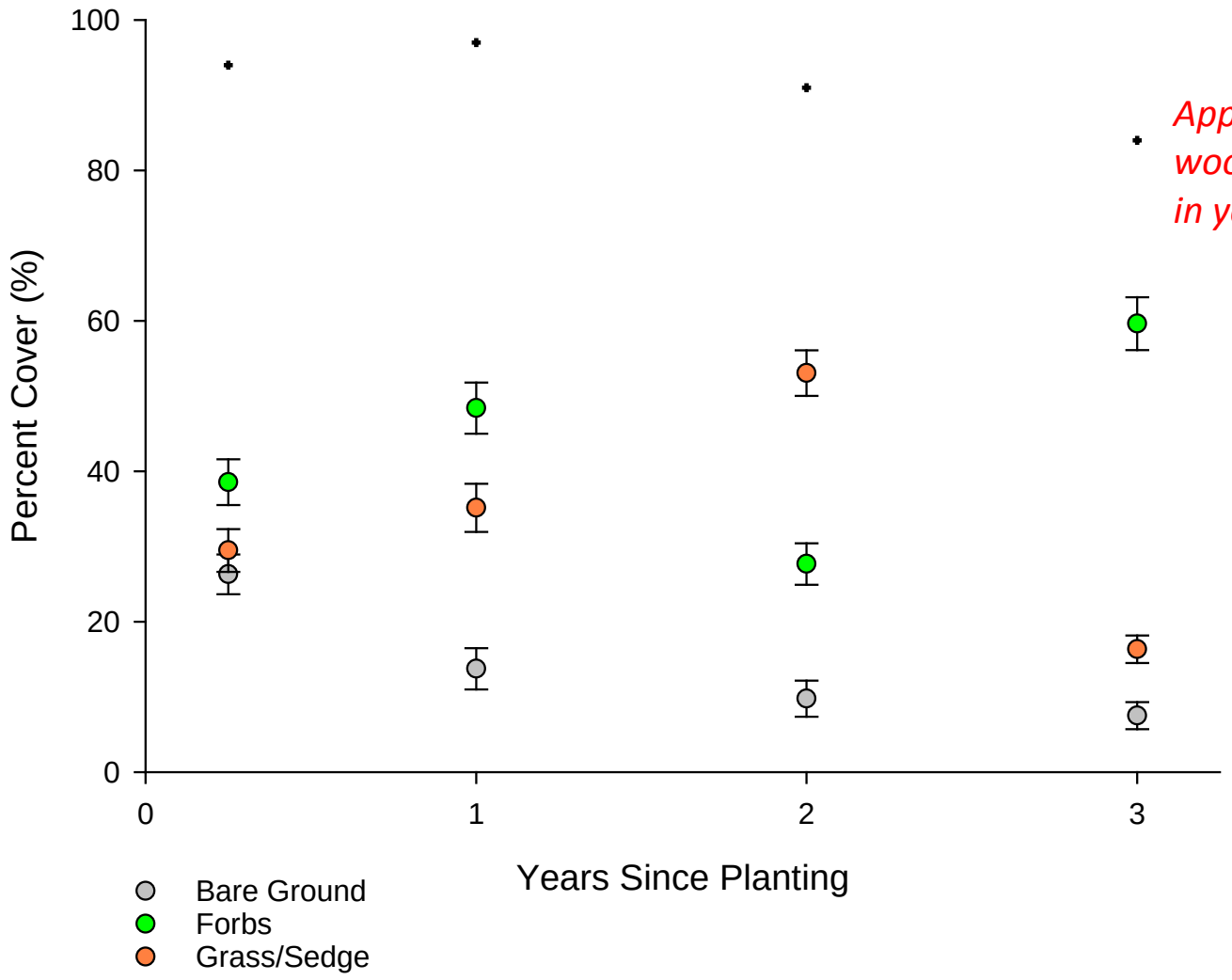
Competing Vegetation (Obj. 3)



Competing Vegetation (Obj. 3)

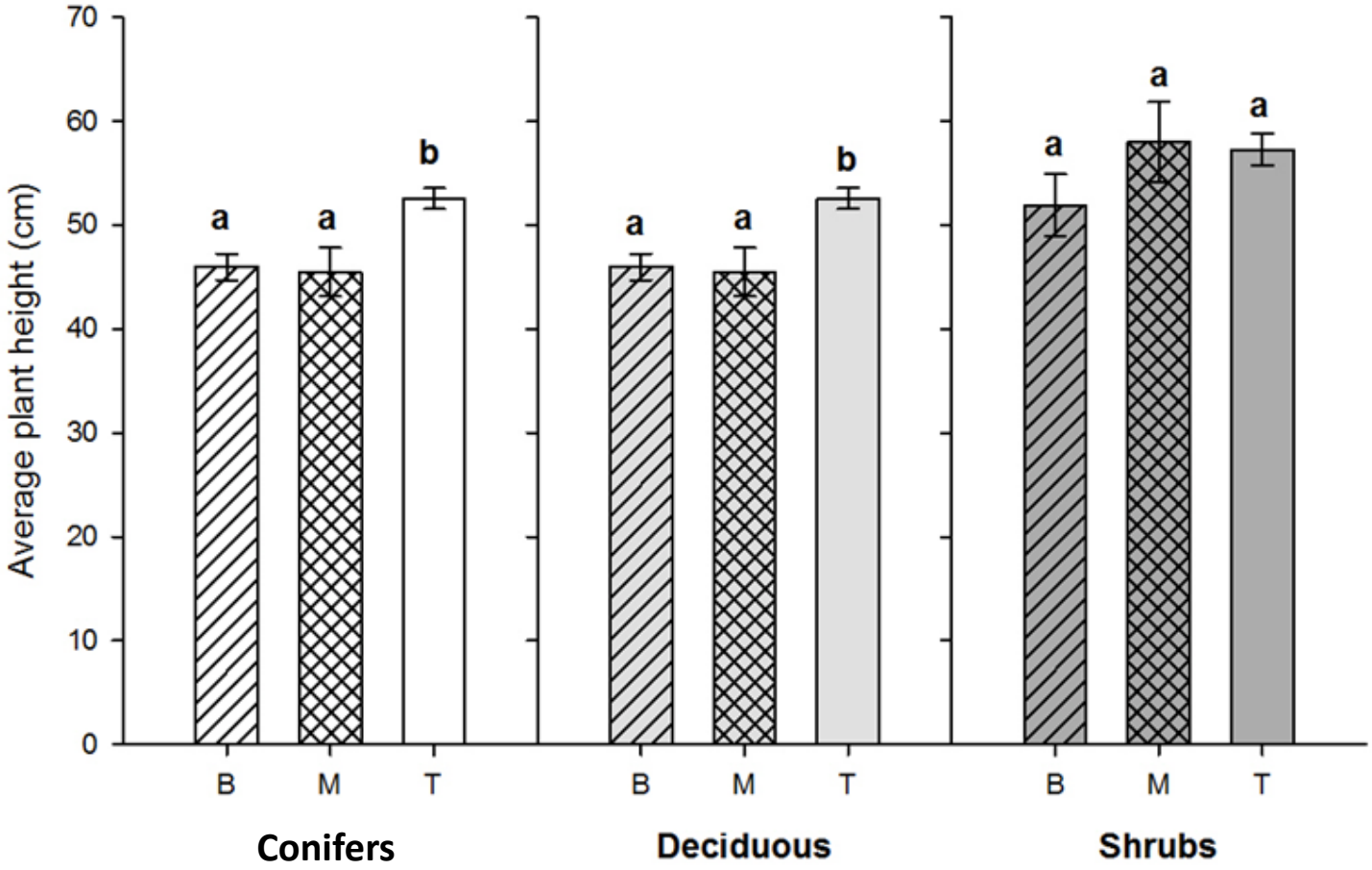


Competing Vegetation (Obj. 3)



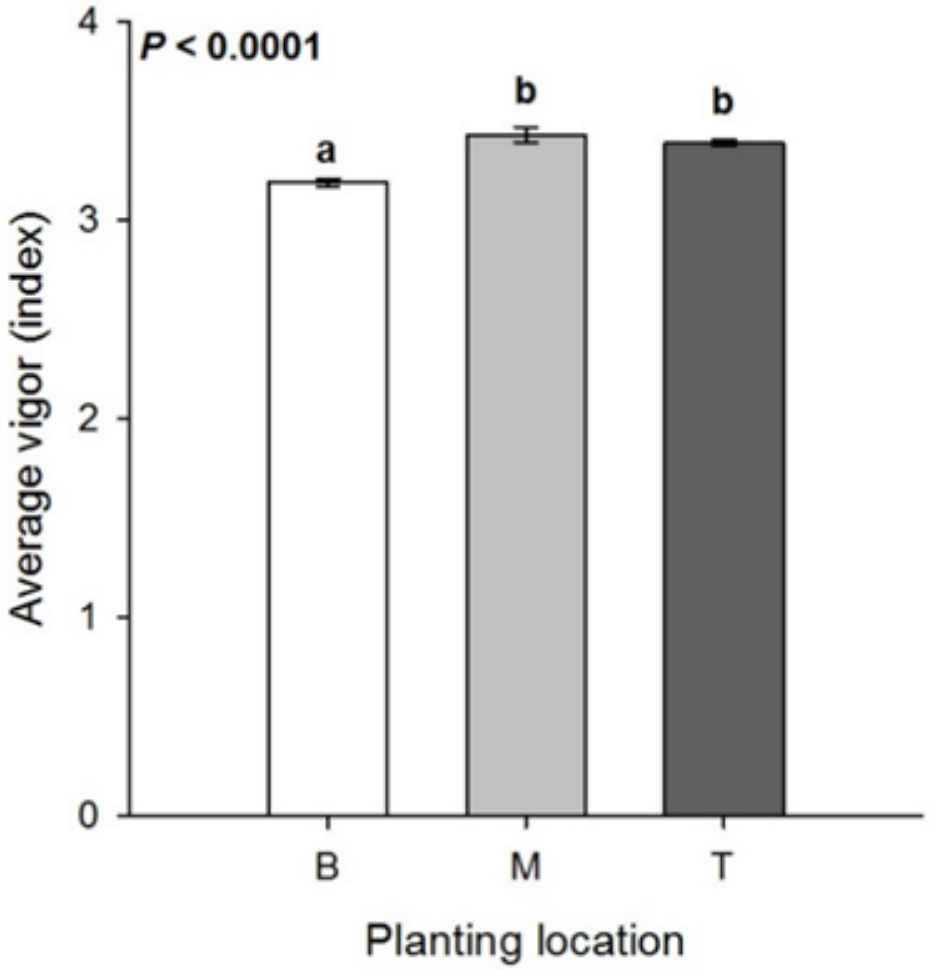
Approx. 10% woody vegetation in year 3.

Planting Position (Obj. 4)



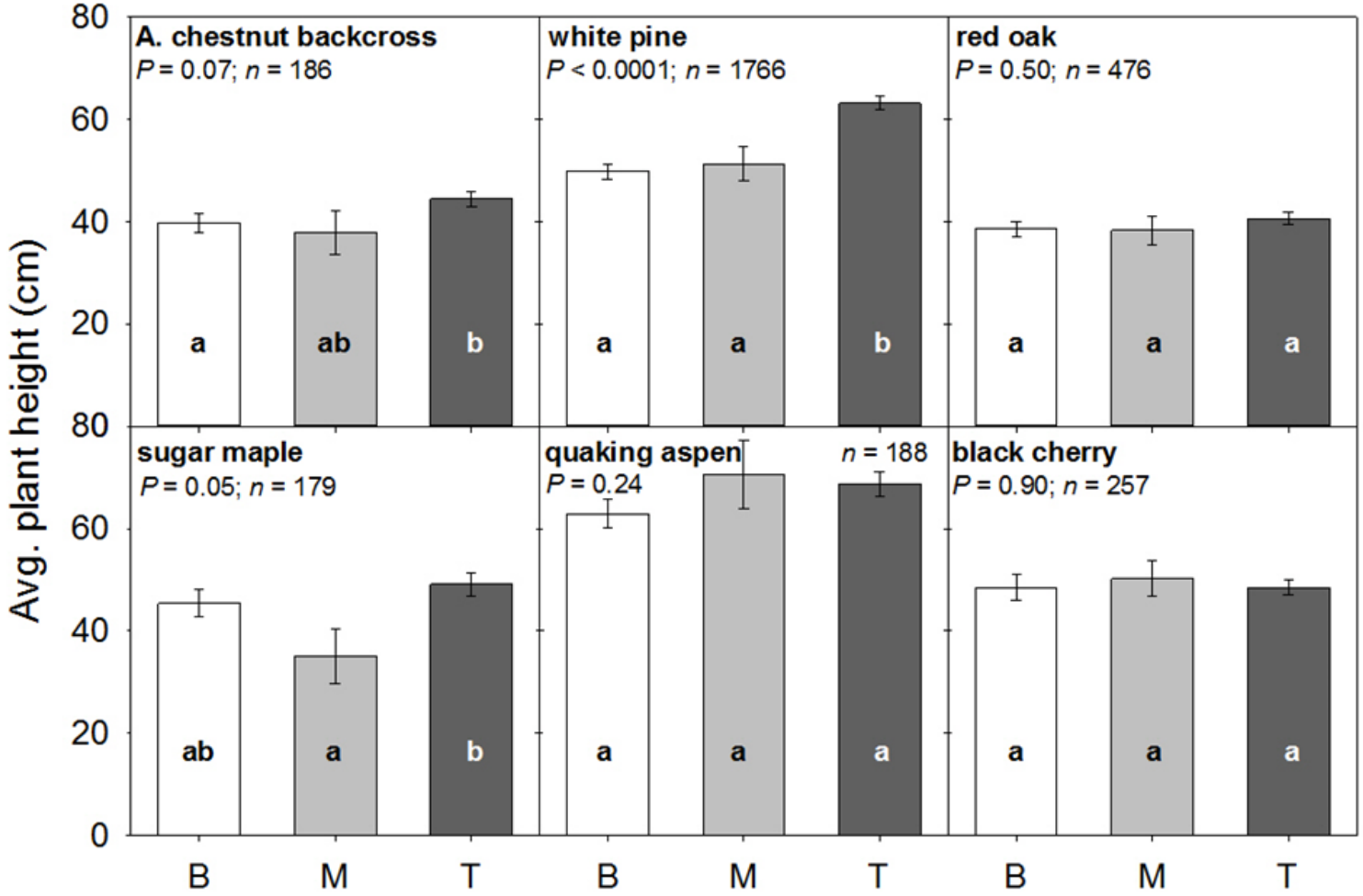
Average plant height for bottom (B), middle (M), and top (T) planting locations for each plant group. Different letters indicate significant ($P<0.05$) location differences within each plant group.

Planting Position (Obj. 4)



Across all four phases
Average vigor by planting location. Different letters indicate significant (P<0.05) location differences.

Planting Position (Obj. 4)



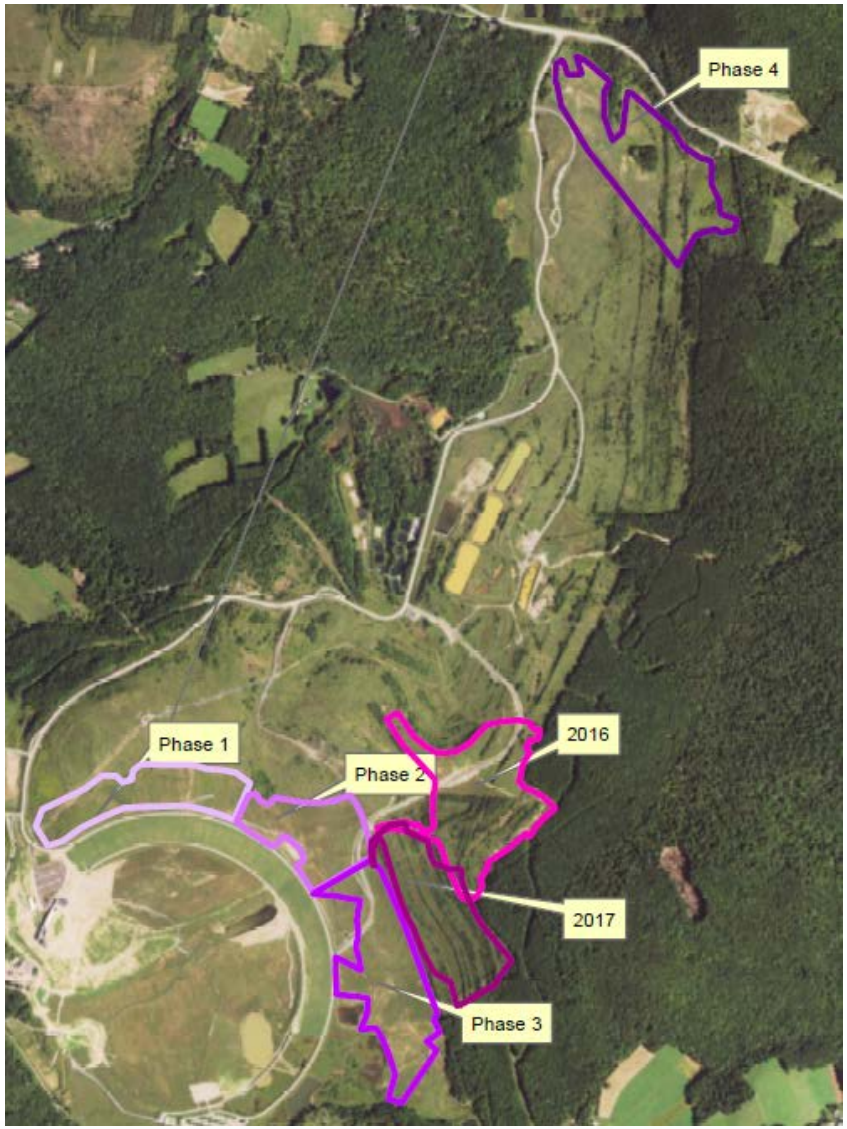
**Different letters indicate significant (P<0.05)*

Future Work

Summer 2017 – we will remeasure phases I-IV and establish permanent plots in Phases V & VI.

More intensive sampling in specially designated sections where red spruce and resistant American elm were planted (line-intersect method with multiple transects)

Long-term - Continue to track stand development across all planted sites.



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