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Vegetable Variety, Cultural and Irrigation Management Studies in 2003

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Planting Date and Variety Effects on Cabbage Yield and Head Traits

This project was designed to assist the Ohio cabbage industry in identifying combinations of planting dates and varieties that optimize yield and head traits. Previous reports strongly suggest that yield and important head traits (e.g., size, weight, density, freedom from physiological disorders, core size, etc.) are uniquely influenced by variety and planting date. Therefore, planting date-variety tests are required to maximize the potential return from local-regional cabbage production and to increase the understanding of how cabbage plants and crops respond to environmental conditions.

Materials and Methods

See Table 1 for a list of the genotypes examined in the fresh market/slaw and kraut studies. See Table 2 for a summary of seasonal temperature and rainfall for the experimental site.

Transplant Production. Entries were solicited from cooperating seed companies in winter 2002-2003. Transplants were seeded in spring, allowed to develop 2-4 true leaves in the greenhouse, and hardened-off before planting into the field.

Plot Establishment. A randomized complete block design was used in each study. Each study contained four replications per entry per planting and two planting dates (May 24 and June 24). The fresh market/slaw study included twelve genotypes and the kraut study included thirteen genotypes. Two-row plots were established with a Holland finger transplanter. Each row was 15 ft. long with 30 in. between rows and 11 in. (fresh market/slaw) and 18 in. (kraut) between transplants. A mix of 125 lb./A of 46-0-0, 150 lb./A of 18-46-0, and 350 lb./A of 0-0-60 fertilizer was broadcast-applied on April 21, 2003 and later incorporated before planting. A nutrient starter solution (0.7 qt. 10-34-0/50 gal. water) was delivered next to the transplants.

Plot Maintenance. Dead transplants were replaced (if possible) within one week of initial planting. Standard pest management strategies based on scouting, thresholds, and applications of labeled pesticides were employed.

Data Collection (at Harvest). Harvest readiness for individual entries was estimated from published maturity information and visual examination of the four plots per entry. At maturity, all heads were collected from within the center 10 ft. of both rows in each plot. Heads were scored as marketable or unmarketable (too small, split, rotten, or containing evidence of blackrot or tipburn) and weighed as a group. Five marketable heads were then selected at random from the harvested group for further evaluation. Five outer leaves were removed from each head before they were re-weighed individually. Heads were then cut in half longitudinally and the core length and base width as well as the head polar and equatorial diameters of each head were recorded. Half of the head was then cut longitudinally a second time, this quarter head was weighed, dried, and re-weighed for percent dry weight calculation.

Statistical Analysis. Head density was calculated using head weight and average diameter values. Likewise, the percent of the head volume contained in the core was calculated using head average diameter and core length and base width. Replicate averages were calculated and used in means analysis. Main effects and interactions of planting date, entry, and replicate were analyzed with fully specified model statements in SAS (alpha = 0.05). Fisher's Least Significant Difference test (alpha = 0.05) was used to analyze the effect of planting date, replicate, and genotype.

Results

Both Studies. The planting date-x-genotype interaction was significant (alpha = 0.05) for the majority of head and core traits (Tables 3, 9). Planting in May 24 versus June 24 tended to result in smaller, lighter and slightly less dense heads.

Fresh Market/Slaw Study. Data are contained in Tables 3-8. Marketable yield was greater in May- versus June-planted crops (Table 4). Marketable yield in the May planting ranged from 12.6 ton/A to 36.5 ton/A and from 13.8 ton/A to 30.6 ton/A in the June planting (Table 5). Average head weight ranged from 1673 g (3.7 lb) to 2578 g (5.7 lb) in the May planting and from 1500 g (3.3 lb) to 2694 g (5.9 lb) in the June planting (Table 6, 7). Average head density ranged from 0.705 g/cm^3 to 0.895 g/cm^3 in the May planting and from 0.731 g/cm^3 to 0.913 g/cm^3 in the June planting (Table 6, 7). Marketable yield of nine of ten entries listed in Table 8 was statistically similar following planting in May and June. In four entries, none of the ten traits studied were impacted by planting date while in seven entries, 1-3 of the ten traits were affected by planting date (Table 8).

Kraut Study. Data are contained in Tables 9-14. Marketable yield in the May planting ranged from 14.9 ton/A to 42.2 ton/A (Table 11). Marketable yield in the June planting ranged from 26.4 ton/A to 44.7 ton/A (Table 11). Average head weight ranged from 2161 g (4.8 lb) to 3780 g (8.3 lb) in the May planting and from 2636 g (5.8 lb) to 3640 g (8.0 lb) in the June planting (Table 12, 13). Average head density ranged from 0.738 g/cm^3 to 0.885 g/cm^3 in the May planting and from 0.790 g/cm^3 to 0.906 g/cm^3 in the June planting (Table 12, 13). Marketable yield for four of seven entries was similar after planting in May- versus June planting and head equatorial diameter and core length were similarly unaffected by planting date in six entries and seven entries, respectively (Table 14). In three entries, at least five of the ten traits were affected by planting date (Table 14).

Ranking the Varieties.

Varieties were ranked from high-low for total and marketable yield and average head weight and density following spring and summer planting in 2003. Then, the rankings for each variety were added for a total score. The lower the value, the better the rank. Rankings were based on the information contained in the tables found later in this report. Obviously, cabbage varieties should be chosen based on a number of factors, including the ones used to rank the varieties as described above. Depending on their market, growers and processors also need to consider

maturity, appearance, flavor, resistance to diseases and insects, and other factors in selecting varieties. Observations on a number of these factors from the evaluations are provided below.

Conclusions

The following varieties had the best (i.e., lowest) total rank-sum score for marketable yield, average head weight, and head density (spring, summer data combined):

Fresh market/slaw:	HMX 3241, Blue Thunder, Royal Dynasty, Cambria F1
Sauerkraut:	Almanac, Score, GZG 239, Moreton

Table 1. Number of days to harvest (DTH) for twenty-five genotypes of fresh market/slaw-and kraut-type cabbage planted on May 24 and June 24, 2003 at the OARDC Vegetable Crops Research Branch in Fremont, OH.

Study	Entry Name	Entry #	Company	May 24 DTH	June 24 DTH
Fresh Market/Slaw					
	Artost	1	Bejo	68	65
	ATX-151	2	American Takii	68	65
	Blue Thunder	3	Harris Moran	95	92
	Bravo	4	Harris Moran	95	.
	Cambria F1	5	Bejo	75	79
	Golden Dynasty	6	Seminis	68	65
	HMX 3241	7	Harris Moran	95	92
	Platinum Dynasty	8	Seminis	75	.
	Rotunda FA	9	Bejo	87	85
	Royal Dynasty	10	Seminis	87	85
	Ruby King/Red T-690	11	American Takii	87	85
	XCB 2329	12	Sakata	87	85
Processing/Kraut					
	Almanac	1	Bejo	87	92
	Genesee	2	Seminis	101	92
	GZG 239	3	Siegers	101	120
	Hinova	4	Bejo	116	120
	HMX 0222	5	Harris Moran	116	106
	HMX 0224	6	Harris Moran	116	120
	Mentor F1	7	Bejo	102	106
	Milestone F1	8	Bejo	101	92
	Moreton	9	Reeds	116	106
	NIZ-17-695	10	Vilmorin	87	92
	NIZ-17-698	11	Vilmorin	110	99
	Otorino	12	Vilmorin	110	99
	Score	13	Bejo	110	99

Table 2. Climatic data for fresh market and kraut cabbage studies planted at the OARDC Vegetable Crops Research Branch in Fremont, Ohio in 2003.

Fresh Market and Kraut Studies	---- Avg. temp. (F) ----		---------- Precipitation (in.) ----------		
	High	Low	Actual	Normal	-/+ Normal
Planting 1 (May 24)					
May 24 - June 17(25 days)	71.6	49.7	3.20	3.51	-0.31
June 18 - Aug. 6 (50 days)	82.4	58.2	7.89	5.89	2.00
Aug. 7 - Aug. 31 (25 days)	83.2	59.3	1.57	2.81	-1.24
Total			12.66	12.21	0.45
Planting 2 (June 24)					
June 24 - July 18 (25 days)	85.0	60.6	2.89	3.24	-0.35
July 19 - Sept. 6 (50 days)	81.0	57.6	8.35	5.55	2.80
Sept. 7 - Oct. 1(25 days)	73.8	46.1	2.26	2.43	-0.17
Total			13.50	11.22	2.28

Table 3. Analysis of variance results for an experiment studying the impact of planting date and genotype on fresh market/slaw-type cabbage yield and head traits in Ohio in 2003.

			Head				Core			
					diameter					
Source	Yield (ton/A) total	Yield (ton/A) marketable	weight (g)	density (g/cm^3)	polar (cm)	equatorial (cm)	length (cm)	base width (cm)	percent of head volume	percent dry weight
	Pr > F									
Planting Date (PD)	NS	NS	NS	<0.0001	0.0959	NS	0.0522	0.0223	NS	NS
Genotype (G)	0.0184	0.0531	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
PD x G	NS	NS	0.0898	NS	0.0620	0.0445	0.0119	<0.0001	<0.0001	0.1627

Table 4. Influence of planting date on yield and head traits for twelve genotypes of fresh market/slaw-type cabbage planted on May 24 and June 24, 2003 in Ohio.

			Head				Core			
					diameter					
Planting Date	Yield (ton/A) total	Yield (ton/A) marketable	weight (g)	density (g/cm^3)	polar (cm)	equatorial (cm)	length (cm)	base width (cm)	percent of head volume	percent dry weight
5/24/03 (N=44)	30.5a	26.6a	2036	0.79	16.50	17.40	6.70	3.30	0.40	6.50
6/24/03 (N=29)	25.9b	21.3b	2060	0.83	16.40	17.30	6.50	3.20	0.39	6.40
$LSD_{(0.05)}$	4.34	4.62	142.0	0.020	0.42	0.45	0.31	0.08	0.040	0.32

Table 5. Average yield of twelve genotypes of fresh market/slaw-type cabbage planted on May 24 and June 24, 2003 at the OARDC Vegetable Crops Research Branch in Fremont, OH.

Entry		Planting Date (2003)			
		May 24		June 24	
		Yield (ton/A)			
Name	#	total	marketable	total	marketable
Artost	1	29.1	26.9	26.6	22.4
ATX-151	2	29.3	23.5	25.5	14.6
Blue Thunder	3	33.6	25.3	34.4	28.0
Bravo	4	39.4	35.2	.	.
Cambria F1	5	32.7	31.6	33.1	30.6
Golden Dynasty	6	25.7	17.8	23.0	14.9
HMX 3241	7	42.8	36.5	26.6	20.1
Platinum Dynasty	8	29.0	27.5	.	.
Rotunda FA	9	20.9	18.5	25.6	23.3
Royal Dynasty	10	33.8	31.2	30.7	28.0
Ruby King/Red T-690	11	32.9	30.6	16.4	13.8
XCB 2329	12	14.6	12.6	22.9	20.5
CV		32.6	39.4	26.4	37.2
Pr > F		0.0254	0.0696	0.0895	0.1864
$LSD_{(0.05)}$		15.32	16.09	12.40	14.35

Table 6. Head and core traits for twelve genotypes of fresh market/slaw-type cabbage planted on May 24, 2003 at the OARDC Vegetable Crops Research Branch in Fremont, OH.

Entry		Head					Core			
				diameter						
Name	#	weight (g)	density (g/cm^3)	polar (cm)	equatorial (cm)	height/ width ratio	length (cm)	base width (cm)	percent of head volume	percent dry weight
Artost	1	1845	0.761	16.9	16.5	1.02	7.3	3.3	0.39	5.5
ATX-151	2	1815	0.705	17.3	16.7	1.04	6.2	3.4	0.39	5.5
Blue Thunder	3	2183	0.854	15.8	18.0	0.88	7.5	3.5	0.45	6.9
Bravo	4	2548	0.825	16.3	19.6	0.83	7.5	3.5	0.39	7.8
Cambria F1	5	1785	0.761	16.9	16.1	1.05	7.1	3.1	0.34	6.9
Golden Dynasty	6	1673	0.763	15.9	16.2	0.98	6.8	3.5	0.56	6.0
HMX 3241	7	2578	0.793	16.3	20.4	0.80	7.7	3.3	0.29	6.7
Platinum Dynasty	8	1693	0.775	15.9	16.2	0.99	5.7	3.4	0.48	6.7
Rotunda FA	9	2480	0.742	18.6	18.5	1.01	8.6	3.4	0.31	5.9
Royal Dynasty	10	2315	0.799	17.8	17.6	1.01	4.7	3.2	0.34	6.3
Ruby King/Red T-690	11	1863	0.895	15.3	16.3	0.94	6.3	3.0	0.36	6.9
XCB 2329	12	1730	0.766	15.7	16.8	0.94	5.8	3.7	0.59	7.4
CV		14.3	3.2	5.0	5.3	3.8	9.3	5.1	22.7	9.4
Pr > F		0.0001	<0.0001	0.0009	<0.0001	<0.0001	<0.0001	0.0014	0.0032	0.0002
$LSD_{(0.05)}$		454.0	0.0400	1.28	1.44	0.060	0.97	0.26	0.140	0.95

Table 7. Head and core traits for ten genotypes of fresh market/slaw-type cabbage planted on June 24, 2003 at the OARDC Vegetable Crops Research Branch in Fremont, OH.

		Head					Core			
				diameter		height/		base	percent	percent
Entry		weight	density	polar	equatorial	width	length	width	of head	dry
Name	#	(g)	(g/cm^3)	(cm)	(cm)	ratio	(cm)	(cm)	volume	weight
Artost	1	1697	0.842	15.4	15.9	0.97	5.9	3.2	0.42	5.8
ATX-151	2	1500	0.731	15.7	15.7	1.00	5.2	3.1	0.38	5.5
Blue Thunder	3	2694	0.873	16.7	19.3	0.87	7.7	4.2	0.63	7.1
Cambria F1	5	2335	0.827	17.1	18.0	0.95	8.0	2.8	0.21	5.1
Golden Dynasty	6	1880	0.775	17.0	16.3	1.05	6.9	3.2	0.36	5.6
HMX 3241	7	2240	0.826	16.4	18.2	0.90	5.8	4.1	0.71	7.2
Rotunda FA	9	2283	0.796	17.2	18.0	0.96	7.5	2.8	0.22	6.0
Royal Dynasty	10	2170	0.842	16.6	17.3	0.96	5.3	2.9	0.26	6.3
Ruby King/Red T-690	11	1765	0.913	14.9	15.9	0.94	6.4	2.8	0.31	7.4
XCB 2329	12	1958	0.811	15.4	17.9	0.86	6.0	3.2	0.40	6.8
CV		13.70	4.78	5.73	5.29	2.35	9.78	4.35	20.71	11.52
Pr > F		0.0027	0.0033	0.0521	0.0012	<0.0001	0.0009	<0.0001	<0.0001	0.0252
LSD $_{(0.05)}$		560.0	0.079	1.83	1.81	0.040	1.27	0.28	0.158	1.46

Table 8. Influence of planting date on yield and head traits of ten genotypes of fresh market/slaw-type cabbage planted on May 24 and June 24, 2003 at the OARDC Vegetable Crops Research Branch in Fremont, OH. A shaded area indicates that planting date had a significant effect on the variables listed within the genotype according to the Fisher Least Significant Difference test (alpha = 0.05). Analysis based on the mean of four replicates per planting.

Entry		Yield (ton/A)		Head				Core				# of 10 traits affected by planting date
				weight	density	diameter (cm)		length	base width	% of head	percent dry	
Name	#	total	marketable	(kg)	(g/cm^3)	polar	equatorial	(cm)		volume	weight	
Artost	1											3
ATX-151	2											0
Blue Thunder	3											2
Cambria F1	5											6
Golden Dynasty	6											0
HMX 3241	7											3
Rotunda FA	9											3
Royal Dynasty	10											1
Ruby King/Red T-690	11											3
XCB 2329	12											1
number comparisons of 10 significant		1	1	1	4	1	1	2	6	4	1	

Table 9. Analysis of variance results for an experiment studying the impact of planting date and genotype on kraut-type cabbage yield and head traits in Ohio in 2003.

			Head				Core			
	Yield (ton/A)				diameter					
Source	total	marketable	weight (g)	density (g/cm^3)	polar (cm)	equatorial (cm)	length (cm)	base width (cm)	percent of head volume	percent dry weight
	Pr > F									
Planting Date (PD)	0.0611	0.1063	0.0047	0.0113	0.0378	0.0490	NS	<0.0001	<0.0001	NS
Genotype (G)	0.0008	0.0159	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001
PD x G	0.0080	0.0290	0.0015	0.0008	NS	0.0048	NS	<0.0001	0.0001	NS

Table 10. Influence of planting date on yield and head traits for thirteen genotypes of kraut-type cabbage planted on May 24 and June 24, 2003 in Ohio.

			Head				Core			
Planting	Yield (ton/A)				diameter					
Date	total	marketable	weight (g)	density (g/cm^3)	polar (cm)	equatorial (cm)	length (cm)	base width (cm)	percent of head volume	percent dry weight
5/24/03 (N=54)	33.8b	30.9b	2826	0.828	18.3	18.9	6.90	3.44	0.34	7.68
6/24/03 (N=50)	37.5a	34.6a	3042	0.847	18.6	19.2	6.81	3.89	0.46	7.84
$LSD_{(0.05)}$	3.12	3.59	165	0.014	0.35	0.44	0.30	0.10	0.0300	0.71

Table 11. Average yield of thirteen genotypes of kraut-type cabbage planted on May 24 and June 24, 2003 at the OARDC Vegetable Crops Research Branch in Fremont, OH.

		Planting Date (2003)			
		May 24		June 24	
Entry		Yield (ton/A)			
Name	#	total	marketable	total	marketable
Almanac	1	41.0	33.9	45.5	38.6
Genesee	2	30.3	26.5	30.9	27.4
GZG 239	3	34.8	32.3	45.6	44.7
Hinova	4	16.3	14.9	37.2	36.2
HMX 0222	5	30.0	28.8	40.0	35.7
HMX 0224	6	30.4	27.6	37.1	34.4
Mentor F1	7	26.1	20.7	36.1	33.4
Milestone F1	8	35.8	33.8	34.0	26.4
Moreton	9	42.8	40.4	36.1	35.4
NIZ-17-695	10	35.1	32.3	33.1	31.4
NIZ-17-698	11	37.4	32.3	38.5	36.8
Otorino	12	45.9	42.2	35.9	31.7
Score	13	44.6	40.1	39.8	37.6
CV		24.19	30.72	20.78	25.79
Pr > F		0.0001	0.0022	0.2576	0.2482
$LSD_{(0.05)}$		12.25	14.22	11.07	12.67

Table 12. Head and core traits of thirteen genotypes of kraut-type cabbage planted on May 24, 2003 at the OARDC Vegetable Crops Research Branch in Fremont, OH.

Entry		Head					Core			
				diameter		height/		base	percent	percent
Name	#	weight (g)	density (g/cm^3)	polar (cm)	equatorial (cm)	width ratio	length (cm)	width (cm)	of head volume	dry weight
Almanac	1	3155	0.780	19.8	19.6	1.01	5.9	3.6	32	6.4
Genesee	2	2427	0.836	17.1	18.2	0.94	8.0	3.7	49	8.0
GZG 239	3	2745	0.822	18.5	18.6	0.99	6.6	3.9	47	7.9
Hinova	4	2161	0.885	16.9	16.5	1.03	7.2	2.9	28	12.4
HMX 0222	5	2257	0.876	16.5	17.3	0.96	5.9	3.8	55	9.5
HMX 0224	6	2340	0.843	17.3	17.2	1.01	6.5	3.4	41	8.4
Mentor F1	7	2523	0.876	16.9	18.3	0.93	7.5	3.2	32	7.3
Milestone F1	8	2715	0.881	18.1	18.0	1.01	6.3	3.3	30	7.3
Moreton	9	3780	0.857	19.0	21.7	0.88	8.8	3.3	21	7.3
NIZ-17-695	10	2548	0.738	18.8	18.5	1.02	6.8	3.2	27	7.0
NIZ-17-698	11	2698	0.779	18.5	18.9	0.98	5.2	3.6	36	6.6
Otorino	12	3630	0.769	20.4	21.2	0.97	7.9	3.3	21	5.7
Score	13	3493	0.853	19.5	20.3	0.96	7.3	3.6	31	6.1
CV		13.1	4.0	4.5	5.6	3.6	7.8	6.0	19.8	28.08
Pr > F		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.018
$LSD_{(0.05)}$		567.0	0.0500	1.25	1.61	0.053	0.82	0.31	0.100	3.29

Table 13. Head and core traits of thirteen genotypes of kraut-type cabbage planted on June 24, 2003 at the OARDC Vegetable Crops Research Branch in Fremont, OH.

Entry		Head					Core			
				diameter		height/		base	percent	percent
Name	#	weight (g)	density (g/cm^3)	polar (cm)	equatorial (cm)	width ratio	length (cm)	width (cm)	of head volume	dry weight
Almanac	1	3640	0.885	19.5	20.1	0.97	6.6	3.9	40	5.8
Genesee	2	2636	0.826	18.0	18.4	0.98	7.5	4.2	64	8.3
GZG 239	3	3599	0.863	19.8	20.1	0.99	7.3	4.6	60	8.3
Hinova	4	2813	0.902	17.7	18.4	0.97	6.8	4.1	57	8.9
HMX 0222	5	2850	0.906	17.4	18.8	0.93	6.5	3.6	41	8.3
HMX 0224	6	2993	0.881	18.3	18.8	0.98	6.1	4.5	74	9.2
Mentor F1	7	2755	0.868	17.3	19.0	0.91	7.3	3.3	31	7.9
Milestone F1	8	2933	0.840	19.0	18.6	1.03	5.7	3.6	40	6.1
Moreton	9	2808	0.792	18.4	19.4	0.95	8.1	3.2	25	8.9
NIZ-17-695	10	2993	0.817	18.3	19.8	0.92	7.1	3.4	27	6.6
NIZ-17-698	11	3213	0.802	19.6	19.8	0.99	5.3	4.3	51	7.4
Otorino	12	3248	0.790	20.2	19.5	1.04	6.9	3.9	39	6.8
Score	13	3175	0.858	18.8	19.6	0.96	7.2	4.2	52	7.3
CV		14.37	4.15	4.85	5.89	4.03	13.11	7.43	21.20	10.73
Pr > F		0.0713	<0.0001	0.0005	0.4013	0.0013	0.0046	<0.0001	<0.0001	0.0003
$LSD_{(0.05)}$		642.0	0.0520	1.33	1.66	0.058	1.31	0.42	0.14	1.40

Table 14. Influence of planting date on yield and head traits of thirteen genotypes of kraut-type cabbage planted on May 24 and June 24, 2003 at the OARDC Vegetable Crops Research Branch in Fremont, OH. A shaded area indicates that planting date had a significant effect on the variables listed within the genotype according to the Fisher Least Significant Difference test (alpha = 0.05). Analysis based on the mean of four replicates per planting.

Entry		Yield (ton/A)		Head				Core				# of 10 traits affected by planting date
				weight	density	diameter (cm)		length	base width	% of head	percent dry	
Name	#	total	marketable	(kg)	(g/cm^3)	polar	equatorial	(cm)		volume	weight	
Almanac	1											1
Genesee	2											0
GZG 239	3											5
Hinova	4											6
HMX 0222	5											1
HMX 0224	6											2
Mentor F1	7											1
Milestone F1	8											1
Moreton	9											4
NIZ-17-695	10											1
NIZ-17-698	11											5
Otorino	12											1
Score	13											3
number comparisons of 13 significant		4	3	4	2	2	1	0	5	7	3	

Planting Date and Variety Evaluation for New and Familiar Crops Grown on Muck Soils

Planting date and variety selection are key to the success of intense vegetable production, especially on Ohio's organic soils. Offering a diverse set of commodities also increases market opportunities. The goal of this project was to test the response of varieties of new and familiar crops to different planting dates on muck soils.

Materials and Methods

Study Development and Transplant Production. Entries were solicited from cooperating seed companies in Winter 2002-2003 (Table 1). Specific requests were made of seed companies to submit standard varieties and experimental material. Basil, kohlrabi, lettuce, and radicchio were seeded in early spring and mid-summer, allowed to develop 2-4 true leaves in a climate-controlled greenhouse, and hardened-off before field planting. Arugula and radish plots were direct-seeded.

Plot Establishment. Commodities were planted in separate studies. A randomized complete block design containing two planting dates and four replications per entry per planting was employed in each study. Planting dates were June 19 and August 28 (arugula), June 11 and July 31 (basil), June 18 and July 30 (kohlrabi), May 28 and July 17 (lettuce), June 17 and July 30 (radicchio), May 23 and September 5 (radish). For all studies, three-row plots were established by machine- and hand placement of transplants or seed, immediately followed by irrigation. Row length was 15 ft., with 19 in. between rows and 10 in. between transplants. The arugula and radish plots were sown with a precision belt seeder.

Plot Maintenance. Dead transplants were replaced (if possible) within three days of initial planting. Standard pest management strategies based on scouting, thresholds, and application of labeled pesticides were employed in all studies.

Data Collection (Field). Plots were reviewed twice per week. Notes on plant appearance and other traits were taken at plant/crop maturity.

Data Collection (at Harvest). Harvest readiness was determined by visual assessment and with the aid of published maturity information. At harvest, all plants in the center 10 ft of the center row in each plot were removed and evaluated for size, weight, appearance and other characteristics.

Results And Conclusions

Table 2: Arugula total and marketable yield, percent marketable yield and sample dry weight

Table 3: Kohlrabi plant characteristics and yield

Table 4: Basil plant characteristics and yield for both harvests

Table 5: Radicchio head dimensions and yield

Table 6: Radish yield

Table 7: Lettuce head weight and comments

Results from this study suggest that few climate- and soil-based barriers exist to successful production of high quality arugula, basil, kohlrabi, and radicchio crops on Ohio's muck soils. Under the conditions of this experiment, total and marketable yield and other characteristics of these crops were similar to those in areas where arugula, basil, kohlrabi, and radicchio production are more common. However, more research is needed to identify and implement optimal production strategies for these crops in Ohio. For example, basil has many market uses (e.g., fresh herb, industrial oil). For fresh markets, it may be harvested once or many times and sold as a loose leaf product or as intact stems with or without roots attached, depending on market, variety, labor availability, etc. In this study, whole basil plants were "pinched" (flowers removed), to encourage vegetative growth, and then harvested and evaluated once. Although established for the majority of the season, basil plantings contained no noticeable insect pest populations. Therefore, they were rarely sprayed. However, compared to basil produced elsewhere, basil grown in this study appeared to have shorter stems but a greater leaf-to-stem mass ratio. Therefore, it may benefit the industry to focus future research on the use of repeated harvests of basil leaves from relatively smaller, potentially low input plantings or once-over harvests of intact stems from highly fertilized and irrigated high-density plantings. Similar research is needed to identify and implement cultural, fertility, irrigation, and pest management strategies that maximize the potential economic return from producing arugula, kohlrabi, and radicchio in Ohio. Finally, based on information reported here and direct observations of the plots by growers, the performance of lettuce and radish varieties tested here did not meet or exceed that of current industry standards.

Table 1. Entry list of genotypes grown at the OARDC Muck Crops Research Branch in Celeryville, OH in 2003.

Genotype	#	Name	Seed Source	Notes
Arugula	1	Arugula	Johnny's	
	2	Astro	Johnny's	
	3	Runway	Johnny's	
Basil	1	Genovese Basil	Johnny's	
	2	Genovese Compact Imp.	Johnny's	
	3	Lime	Johnny's	
	4	Mrs. Burns' Lemon	Johnny's	
	5	Sweet Dani	Johnny's	
	6	Thai Magic	Johnny's	
Kohlrabi	1	Kolibri (purple)	Johnny's	
	2	Winner (white)	Johnny's	
Radicchio	1	Chioggia Red Preco #1	Johnny's	
	2	Fiero	Johnny's	
	3	Indigo	Johnny's	
	4	Trevisio Red Preco	Johnny's	
Radish	1	QAX208	Seedway	
	2	QAX225	Seedway	
	3	QAX325	Seedway	
	4	Saxonia	Seedway	
	5	Torero	Seedway	
Lettuce	1	Bennett	Sunseeds	Butterhead
	2	BG 9106	Sunseeds	Butterhead
	3	BG 9107	Sunseeds	Butterhead
	4	Camino Real, M.T.	Siegers	Romaine
	5	Capistrano	Seminis	Romaine
	6	Clemente	Seminis	Romaine
	7	Coastal Star	Siegers	Prepcoat special
	8	Connick	Siegers	Butterhead
	9	Connick	Sunseeds	Butterhead
	10	Esmeralda	Siegers	Prepcoat special HD
	11	Green Day	Seminis	Green leaf
	12	Harmony	Siegers	Butterhead
	13	King Louie	Siegers	Romaine
	14	Klamath	Seminis	Romaine
	15	Krypton	Seminis	Green leaf
	16	Lasting Green	Siegers	Green leaf
	17	Marin	Siegers	Green leaf
	18	North Star	Siegers	Balance Special/Green leaf
	19	Red Tide	Seminis	Red leaf
	20	RX 6304	Seminis	Butterhead
	21	Shining Star	Seminis	Green leaf
	22	Sinatra (BG 9101)	Sunseeds	Butterhead
	23	Sunbelt	Siegers	Romaine
	24	SVR 0203A	Seminis	Green leaf
	25	SVR 0926	Seminis	Green leaf
	26	SVR 3980	Seminis	Romaine
	27	SVR 7053	Seminis	Red leaf
	28	SVR 7062	Seminis	Red leaf
	29	SVR 7998	Seminis	Red leaf
	30	Tehama	Siegers	Splitkote Special green leaf
	31	Winchester	Siegers	Romaine

Table 2. Arugula total and marketable yield, percent marketable yield and sample dry weight for 2003.

Variety		---- Yield (Plants/A) ---- Total	Marketable	------ Yield (lb/A) ------ Total	Marketable	% Marketable Yield by wt	by #	Sample % Dry Weight
Arugula								
	Average	199650.0	87846.0	3441.5	1553.2	45.0	44.3	9.3
	SD	29745.3	17159.8	1549.4	773.9	6.6	7.9	0.8
Astro								
	Average	226512.0	105705.6	5675.5	2885.1	48.2	49.4	8.5
	SD	75084.0	26344.9	1704.8	1475.8	14.8	13.3	0.9
Runaway								
	Average	126324.0	87120.0	2325.0	1596.4	69.0	69.2	9.0
	SD	39141.2	25427.3	1135.7	794.7	7.9	3.7	0.7

Table 3. Kohlrabi plant characteristics and yield in 2003.

		Total Plant FW (kg)	Bulb Marketable FW (kg)	Average Bulb % DW	Marketable Yield (lb/acre)
Winner					
	Average	3.3	1.4	7.8	12943.9
	SD	0.4	0.1	0.37	690.6
Kolibri					
	Average	2.0	1.0	8.0	9147.6
	SD	0.4	0.1	0.88	1352.7
Winner					
	Average	3.1	0.8	5.9	6906.4
	SD	0.7	0.1	0.18	1270.8

Table 4. Basil plant characteristics and yield in 2003. Plantings one and two were harvested July 22 and August 28, respectively.

Planting	Variety		Total Leaf FW (kg)	% DW Leaves	Total Stem FW (kg)	% DW Stems	Total Marketable FW (kg)	Marketable Yield (lb/acre)
1	Genovese Basil	Average	0.3	7.4	0.2	11.4	0.4	2753.43
		SD	0.1	0.8	0.1	1.0	0.2	1189.94
1	Genovese Compact Imp.	Average	0.6	6.1	0.3	11.7	0.9	5506.86
		SD	0.2	0.1	0.1	0.2	0.3	1826.16
1	Lime	Average	0.6	6.8	0.4	13.5	1.0	6435.34
		SD	0.1	1.0	0.1	2.3	0.2	1015.82
1	Mrs. Burns' Lemon	Average	0.6	7.0	0.4	12.9	0.9	5859.04
		SD	0.3	2.0	0.2	1.8	0.5	3354.88
1	Sweet Dani	Average	0.3	7.7	0.3	12.4	0.6	3841.99
		SD	0.1	0.6	0.1	1.1	0.2	1310.21
1	Thai Magic	Average	0.3	8.0	0.2	11.9	0.5	2881.49
		SD	0.1	1.5	0.0	1.1	0.1	713.04
2	Genovese Basil	Average	0.57	11.11	0.39	10.73	0.96	6147.19
		SD	0.21	4.16	0.12	5.38	0.33	2083.46
2	Genovese Compact Imp.	Average	0.67	8.45	0.28	7.94	0.95	6051.14
		SD	0.08	0.54	0.06	0.39	0.12	792.05
2	Lime	Average	0.40	10.04	0.24	11.35	0.64	4072.51
		SD	0.07	1.82	0.02	0.82	0.08	538.79
2	Mrs. Burns' Lemon	Average	0.55	7.73	0.41	11.82	0.96	6147.19
		SD	0.26	0.42	0.24	1.93	0.49	3117.74
2	Sweet Dani	Average	0.60	7.43	0.61	9.93	1.21	7716.00
		SD	0.17	0.89	0.16	0.95	0.32	2025.92
2	Thai Magic	Average	0.60	8.74	0.24	8.10	0.84	5346.77
		SD	0.08	0.11	0.01	0.39	0.08	537.01

Table 5. Radicchio head dimensions and yield in 2003.

Planting	Variety		Average Head (cm) Diameter	Height	Percent Trimmed	Marketable Yield (lb/A) Untrimmed	Trimmed
1	Chioggia Red Preco #1						
		Average	25.25	19.38	16.22	6574.08	5506.86
		SD	2.18	2.74	2.89	1484.32	1261.31
1	Fiero						
		Average	24.42	26.04	17.10	7812.05	6488.70
		SD	0.52	1.12	5.80	713.04	871.73
1	Indigo						
		Average	23.45	21.50	16.76	4567.70	3799.30
		SD	1.94	2.38	1.03	533.18	411.68
1	Treviso Red Preco						
		Average	23.19	29.69	18.51	8628.47	7139.70
		SD	0.72	3.08	1.85	672.35	483.44
2	Chioggia Red Preco #1						
		Average	29.13	22.60	30.80	9348.85	6317.94
		SD	2.20	3.99		2586.81	2254.36
2	Fiero						
		Average	26.50	31.13	11.50	10885.64	9604.98
		SD	1.30	1.44	1.78	2493.19	2032.99
2	Indigo						
		Average	30.08	22.29	38.10	8708.52	5720.30
		SD	3.00	2.69	19.92	2831.98	3699.18
2	Treviso Red Preco						
		Average	26.17	31.33	9.00	8964.65	8110.87
		SD	2.27	3.44	3.15	3186.25	2638.08

Table 6. Radish yield in 2003.

Variety		Total Biomass (kg)	Total Bulb (kg)	Marketable Bulb (kg)	Yield (lb/A)
QAX208					
	Average	2.75	2.09	0.66	15356.24
	SD	1.58	0.66	0.43	13168.79
QAX225					
	Average	2.42	1.76	0.68	16188.62
	SD	1.37	0.10	0.32	10687.99
QAX325					
	Average	3.52	0.52	0.48	13088.34
	SD	1.34	0.32	0.28	7666.43
Saxonia					
	Average	2.99	2.42	0.42	9968.48
	SD	2.37	1.03	0.20	6768.65
Torero					
	Average	3.10	3.05	0.83	18465.02
	SD	2.12	0.51	0.34	11941.95

Table 7. Weight of four untrimmed heads and observations on lettuce planted at the OARDC Muck Branch in 2003.

Planting	Genotype	Weight of 4 Heads Combined (kg) untrimmed	trimmed	Bolt N=NO Y=YES	Tipburn Outer #heads/20	Leaf Morphology flat-curly (1-5)
1	Bennett	2.6	1.4	N	10	2.5
1	BG 9106	2.1	1.1	N	12	1.5
1	BG 9107	2.7	1.7	N	5	1.5
1	Camino Real, M.T.	2.9	2.1	N	6	1.7
1	Capistrano	2.7	2.0	N	0	3
1	Clemente	2.8	2.1	N	2	1.5
1	Coastal Star	2.7	2.1	N	14	2.7
1	Connick	2.5	1.4	N	16	2
1	Esmeralda	2.6	1.8	N	8	2
1	Green Day	2.7	2.2	N	5	5
1	Green Towers	2.7	2.0	N	5	2
1	Harmony	2.4	1.3	N	2	1.5
1	King Louie	2.8	2.1	N	3	2
1	Klamath	2.5	1.9	N	3	1
1	Lasting Green	2.3	1.9	N	0	5
1	Marin	2.6	1.9	N	0	5
1	North Star	2.3	1.6	N	1	4.5
1	Red Tide	2.4	1.8	N	3	3.5
1	RX 6304	2.5	1.3	N	11	2
1	Shining Star	3.2	2.3	Y	1	5
1	Sinatra (BG 9101)	2.4	1.1	N	8	2
1	Sunbelt	2.9	2.1	N	2	2.5
1	SVR 0203A	2.5	1.9	Y	1	5
1	SVR 0926	2.9	2.0	N	0	5
1	SVR 3980	3.4	1.7	N	6	3.5
1	SVR 7053	2.3	1.8	N	0	4
1	SVR 7062	2.3	1.7	N	3	3.5
1	SVR 7998	1.9	1.3	N	0	5
1	Tehama	2.9	2.0	N	1	5
1	Winchester	2.6	2.0	N	0	2.5
2	BG 9107	1.8	1.3			
2	Esmeralda	1.4	1.0			
2	Green Day	2.2	1.8			
2	Lasting Green	2.4	1.8			
2	North Star	1.7	1.5			
2	Red Tide	1.5	1.3			
2	RX 6304	1.7	1.2			
2	Shining Star	2.6	2.1			
2	SVR 7053	2.0	1.8			
2	Tehama	1.8	1.5			

Cabbage Irrigation and Fertigation

Introduction

Irrigation and the supply of nutrients via irrigation water (fertigation) are relatively uncommon practices in Midwest cabbage production, although interest is increasing in the use of these strategies to enhance crop yield and quality. However, little research-based information is available to assist in guiding irrigation use in the region. Adding soluble fertilizers to irrigation water could help offset investments in irrigation-related equipment and resources. Therefore, the goal of this project was to test soil management (irrigation and fertility) regimes in fresh market/slaw- and kraut-type cabbage. This project was also an opportunity to follow-up on previous research done in this lab and elsewhere, which strongly suggests that important crop and head traits are affected by soil moisture and nutrient availability.

Materials and Methods

Transplant Production. Transplants were seeded on April 25 and 29, 2003, allowed to develop 2-4 true leaves in the greenhouse, and hardened-off before planting into the field.

Plot Establishment. The project was completed at the OARDC in Wooster, OH, and consisted of fresh market/slaw- and kraut-type studies, each including two varieties and four treatments. Plots (6 rows wide x 23 ft long) in each study were established on June 25 and 26 (fresh market and kraut, respectively) with a two-row finger-type transplanter and arranged in a randomized complete block design with four replications per treatment (2 varieties x four soil management regimens). Between-row spacing equaled 30 in. and in-row spacing equaled 11 in. (fresh market/slaw) and 18 in. (kraut). Six-row border plots consisting of the same variety were placed between treatment plots to minimize the potential for moisture and nutrient movement off-target. On June 27, irrigation lines (T-Tape, Ackerman Supply Co, Curtice, OH) were laid on the soil surface 6 in. from plant stems along the entire length of the center two rows of each six-row plot.

Fertility and Irrigation Treatment Application. The four fertility and irrigation treatments were: no irrigation with full rate fertilizer (N, P, K) applied broadcast (control 1), irrigation as needed with a full rate of fertilizer (N, P, and K) applied broadcast (irrigation), irrigation with 70% N and K fertilizer applied broadcast, 30% N and K applied through irrigation and 100% P applied broadcast (fertigation), and no irrigation with 70% of N, P, and K applied broadcast and 30% applied as a side-dress at the same time as fertigation (control 2). Target total seasonal nutrient applications were 100 lb/A of N and P and 150 lb/A of K. These targets were set slightly higher than some commercial practices due to excessive pre-plant rainfall that may have leached residual N and P. To reach this target, the following applications were made:

1. Last week of May, before planting, broadcast and incorporate in all plots; 400 lb/A of 19-19-19 (75 lb/A of N, P, K, respectively).

2. June 18 and 19, before planting, broadcast and incorporate in all plots; 54 lb/A of triple superphosphate (25 lb P/A) and 63 lb/A of potassium chloride (38 lb K/A).
3. June 18 and 19, before planting, broadcast and incorporate in Control 1 plots only; 54 lb/A urea (25 lb N/A).
4. July 21, 26-27 days after planting, sidedress to Control 2 plots only; 54 lb/A urea (25 lb N/A) and 32 lb/A muriate of potash (19 lb K/A). Blended material applied by hand as a band to top of soil 4 in. from plant stems along entire length of plot rows.
5. August 7, 33-34 days after planting, inject into irrigation to Fertigation plots only, 27 lb/A urea (13 lb N/A) and 32 lb/A of potassium chloride (19 lb K/A).
6. August 15, 41-42 days after planting, inject into irrigation to Fertigation plots only, 14 lb/A urea (8 lb N/A) and 16 lb/A of potassium chloride (10 lb K/A).
7. August 20, 46-47 days after planting, inject into irrigation to Fertigation plots only, 13 lb/A urea (9 lb N/A) and 16 lb/A of potassium chloride (10 lb K/A).

When irrigation was used to deliver fertilizer (fertigation), irrigation was initiated 30 min prior to fertilizer irrigation, fertilizer was injected (approx. 30-40 min), and irrigation was continued for 30 min after the fertilizer solution had emptied from the tank.

Irrigation was applied without added fertilizer to appropriate plots on the following days in August: 11, 13 (fresh market only), 14 (processing only), 15, and 20. Irrigation was applied until wetting zones from most adjacent emitters (spaced 12 inches apart) had joined for approximately 15 min, which required 1.5-2.5 hr total. Irrigation was scheduled with the "hand-feel" method and TDR readings were taken to correlate instrumented measures of soil moisture content with the "hand-feel" method. Except for August 20 (9:15am – 11:15am), irrigation and fertigation events took place between 11:45am and 4:45pm.

Results

The variety-x-soil management regime (water, fertility) interaction was not significant for any yield or head trait variables (data not shown). Likewise, variety did not affect yield or head trait variables in the fresh market study. Therefore, since variety had little effect on (fresh market study) or acted independently from the soil management regime (kraut study), variety was excluded from additional models testing the effects of soil treatment.

In the fresh market study, total and marketable yields were significantly lower in Control 2 (no irrigation with 70% of N, P, and K applied broadcast and 30% applied as a side-dress at the same time as fertigation) than in other regimes, while differences among remaining regimes were not significant (Table 1). Total and marketable yield were unaffected by soil regime in the kraut study, although both tended to be higher in irrigated and fertigated plots, relative to both types of non-irrigated control plots (Table 1).

Conclusions

The chart below depicts rainfall amounts for the study period in 2003.

Month	Rainfall (in.) in 2003	Normal (40-year average) rainfall (in.)
May	5.36	3.91
June	3.94	3.94
July	7.17	4.10
August	3.74	3.63
September	5.45	3.14
Total	**25.66**	**18.72**

Despite higher than normal rainfall, especially during head initiation and early development (July), total and marketable yields tended to be higher in plots receiving irrigation (with or without added fertilizer) than in non-irrigated plots. For example, regardless of market type, yield values were higher in plots receiving irrigation and broadcast fertilizer than in non-irrigated plots receiving broadcast fertilizer. Yield values were also higher in plots receiving irrigation and broadcasted, banded, and injected fertilizer (fertigation) than in plots receiving no irrigation and broadcasted and banded fertilizer. However, yield values were similar in irrigated and fertigated plots. More study under a wider range of environmental conditions is required to verify these results. Nevertheless, they suggest that irrigation may increase cabbage total and marketable yield under Ohio conditions, even in seasons when rainfall exceeds historical averages. Similar results have been found in previous related studies conducted by this group and involving drip irrigation of mostly fresh market-type varieties. Yield in plots receiving split applications of fertilizer, including application via irrigation water (fertigation), was not significantly greater than in plots receiving split applications of fertilizer but no irrigation. However, injection of fertilizer into irrigation water is expected to increase fertilizer efficiency and, possibly, yield, in cabbage as in other crops.

Table 1. Average yield of two varieties of fresh market/slaw and processing/kraut cabbage subjected to contrasting soil treatments in 2003.

Soil Treatment	Yield (ton/A)			
	Fresh Market/Slaw		Processing/Kraut	
	Total	Marketable	Total	Marketable
Control 1[a]	36.7a	33.8a	39.3a	36.1a
Irrigation[b]	38.8a	37.5a	43.7a	39.8a
Fertigation[c]	34.8a	33.2a	50.6a	38.6a
Control 2[d]	26.5b	24.5b	40.8a	33.2a
CV	21.5	24.5	37.1	32.2
Pr > F	0.0127	0.0185	0.6042	0.7045
$LSD_{(0.05)}$	7.5	8.6	17.5	12.9

[a]Control 1 - no irrigation; full rate fertilizer (N,P,K) applied broadcast

[b]Irrigation - irrigation as needed; full rate fertilizer (N,P,K) applied broadcast

[c]Fertigation - irrigation with 70% N+K fertilizer applied broadcast; 30% N+K applied through irrigation; 100% P applied broadcast

[d]Control 2- no irrigation; 70% fertilizer (N,P,K) applied broadcast; 30% applied as a side dress at same time as fertilizer is injected in fertigation treatment

Table 2. Head and core traits for two varieties of fresh market/slaw and processing/kraut cabbage subjected to contrasting soil treatments in 2003.

	Head					Core			
			diameter		height/		base	percent	percent
Market Type and Soil Treatment	weight (kg)	density (g/cm^3)	polar (cm)	equatorial (cm)	width ratio	length (cm)	width (cm)	of head volume	dry weight
Fresh Market/Slaw									
Control 1[a]	2.6ab	0.803a	17.4a	19.0ab	0.92ab	8.0a	3.5a	0.36	5.4ab
Irrigation[b]	2.9a	0.789a	17.5a	20.4a	0.87b	8.4a	3.5a	0.32	4.2c
Fertigation[c]	2.8a	0.793a	17.4a	20.0ab	0.87ab	8.3a	3.5a	0.32	4.8bc
Control 2[d]	2.2b	0.775a	17.1a	18.0b	0.96a	7.9a	3.5a	0.41	6.0a
CV	18.0	4.8	5.3	10.0	8.9	9.9	4.0	29.3	15.0
Pr > F	0.0359	0.5573	0.8272	0.1394	0.1185	0.6552	0.9420	0.1702	0.0087
$LSD_{(0.05)}$	0.54	0.0465	1.09	2.25	0.095	0.94	0.16	0.128	0.96
Processing/Kraut									
Control 1[a]	3.4a	0.811a	20.0a	20.2a	0.99a	8.8a	4.0a	0.22	6.7ab
Irrigation[b]	3.4a	0.804a	19.6a	20.3a	0.97a	8.9a	3.4a	0.27	5.5b
Fertigation[c]	3.6a	0.834a	20.0a	20.3a	0.99a	8.8a	3.4a	0.24	7.6a
Control 2[d]	3.5a	0.840a	19.9a	19.7a	1.01a	8.2a	3.5a	0.34	6.2ab
CV	27.6	9.4	11.2	13.0	5.6	10.2	31.6	37.7	26.9
Pr > F	0.9745	0.7863	0.9886	0.9688	0.5491	0.4002	0.6918	0.2088	0.2377
$LSD_{(0.05)}$	1.01	0.0842	2.33	2.73	0.058	0.93	1.170	0.109	2.12

[a]Control 1 - no irrigation; full rate fertilizer (N,P,K) applied broadcast

[b]Irrigation - irrigation as needed; full rate fertilizer (N,P,K) applied broadcast

[c]Fertigation - irrigation with 70% N+K fertilizer applied broadcast; 30% N+K applied through irrigation; 100% P applied broadcast

[d]Control 2 - no irrigation; 70% fertilizer (N,P,K) applied broadcast; 30% applied as a side dress at same time as fertilizer is injected in fertigation treatment

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