

Organic Vegetable Production in the North Central U.S: Linking Growth Traits to Adaptation and Weed Suppression

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SUMMARY

The potential for commercial vegetable production in western North Dakota is somewhat limited. However, gardeners, market growers or other, larger-scale operations with access to irrigation would benefit greatly from the identification of crop varieties that are well-suited to the particular climatic conditions. Very little work has been done in this area, and therefore, the objective of this study was to screen several varieties of three different vegetable crops (carrots, potatoes and sweet corn) for their suitability for production in western North Dakota. The linkage of performance with varietal growth characteristics is also of interest, and will be investigated further in years to come.

Yields were determined for all crops, carrots were ranked in terms of visual characteristics, and potatoes and carrots were subject to a taste test. Soil moisture and photosynthetically active radiation was measured in potatoes. Yields of all crops were low, resulting to a great extent from the extremely dry growing season in 2009. Of the carrot varieties screened, Hercules and Napoli generally performed the best, while Sugarsnax 54 was a poor performer. In potatoes, Superior and Red Gold showed some potential, and in sweet corn, Sugar Pearl was the best performer.

INTRODUCTION

Current production of fresh market vegetables in western North Dakota is limited, most notably due to climate conditions. However, interest in organic production and local food systems is growing. Organic farming methods seek to reduce dependence on off-farm inputs while stressing sustainable and ecologically sound production practices. Consonantly, the local foods movement seeks to create a food production and delivery system that identifies and fosters markets for locally grown crops. This system stresses local sourcing of foods whenever possible in order to strengthen regional economies and reduce the transportation time of food, while also striving to provide opportunities for small growers to compete for market share. As food safety and climate considerations gain precedence, the potential for small-scale vegetable production in the form of home or market gardens is anticipated in the region. Depending on the particular crop, availability of irrigation and site specific

characteristics, larger scale production could conceivably be possible as well.

The climate of western North Dakota is characterized by a warm but short growing season, with a frost-free period of approximately 110-130 days. Growing season temperatures average 58-60° F, with a cool spring giving way to a relatively hot summer, averaging 16-24 days above 90° F each year. The climate is sub arid and prone to drought, especially later in the season. Average annual precipitation in western North Dakota is highly variable, but averages 16-17 in. Rainfall occurs predominantly in the spring, with cumulative April-June precipitation averaging 5 to 7 in., and decreases later in the season, with cumulative July-September rainfall averaging 4 to 5.5 in. Breezy conditions prevail throughout the season, with monthly maximum wind speeds averaging approximately 25 mph for April through June, and 23 mph for July through September.

Given the short growing season, low precipitation and windy conditions, a prominent issue for vegetable growers in the region is the identification of varieties and accompanying growth traits that are well suited to the climatic conditions of the region. Organic and conventional growers alike desire varieties that compete well with weeds, are resistant to disease and pest pressure, perform well under dry, windy conditions, and ultimately maintain high yields. Therefore, the objective of this study was to identify vegetable crop varieties suitable for production in this region. The performance of several varieties of three types of common vegetable crops, carrots, potatoes, and sweet corn was assessed using several variables. In future growing seasons, this experiment will be expanded to include not only other species of vegetables, but the number of measured parameters will also be broadened to facilitate the correlation of varietal growth traits with actual performance as evinced by resistance to weed, insect and disease pressure.

MATERIALS AND METHODS

Five varieties of potatoes, six varieties of carrots, and eight varieties of sweet corn were grown in separate experiments during the 2008 growing season (Table 1). Potatoes and carrots followed oat stubble fallow and sweet corn followed field pea. Soil type is a Parshall fine sandy loam. Experimental design was a randomized complete block with four replications for

each crop. Seedbed preparation consisted of one pass with a tandem disk. Sweet corn was seeded in 32 in. rows on May 14 and carrots and potatoes were seeded on May 16 in 32 in. rows and 30 in. rows respectively. Corn was cultivated with a Lorenz 2 row “high trash” cultivator on June 23, and hoed and hand-weeded on June 27, July 2 and August 5 to control persist and in-row weeds. Weed control in carrots was performed by hoeing or hand-weeding as required on June 19, June 24, July 16 and August 18 and in potatoes on June 18, June 27, July 16 and August 18 by the same methods. Weeds occurring in alleys of the carrot study were controlled with a rototiller on June 21. Corn was thinned to a population of 18,000 plants/acre on June 27 and carrots were thinned to approximately 12 plants/row ft on July 22 and 23. Carrots were irrigated with an impact sprinkler on July 3 and August 6, resulting in approximately 2 to 3 in. of supplementary water. Harvest was performed by hand for all crops on August 25 in the case of sweet corn and August 29 in the case of carrots and potatoes.

Yield was determined for all crops, by harvesting a subsection of each whole plot and obtaining weights of the samples. Potato date of flowering was recorded, as was date of corn tasseling. Photosynthetically active radiation at soil surface was assessed in potato on July 21, July 28 and August 6. Three replicate readings were taken from each plot on each date below the plant canopy, while one above canopy reading was also taken in each plot. Volumetric soil moisture content was recorded in Potatoes on July 22, August 5 and August 19 with a Delta-T PR2 Profile Probe. This probe consists of a polycarbonate rod approximately 25 cm in diameter with electronic sensors at fixed intervals along its length. The probe is inserted to a consistent depth via seasonally permanent access tubes, installed on July 16 in each plot of two replicate blocks. Water content measurements were obtained at depths of 3 and 19 in.

Variables recorded in sweet corn included marketable ears/acre, plant height, cob length, cob diameter and number of kernel rows. Early season vigor was also recorded in corn on June 19. This was accomplished by walking through the study and visually ranking the varieties as -1, 0 or +1, which referred to below average, average and above average in terms of vigor, respectively. This procedure was repeated twice, once earlier and once later in the day, and the scores were averaged.

Carrot root length and diameter was recorded, while carrot roots were also visually ranked in categories of “root condition”, which referred to the extent of cracking, blemishes and branching, “uniformity”, which referred to the consistency of the

root appearance within varieties, “true to type”, which referred to the extent of similarity between the sample and the varietal standard, and “visual appeal”, which described the overall attractiveness of the roots. A “size” category was also included, which pertained not to relative size differences between varieties, but to the extent to which variety best represented an acceptable fresh market carrot size in the opinion of the individual performing the rankings. Rankings were performed by randomly selecting ten roots from each variety, visually assessing the qualities described above and ranking on a scale of 1 to 6 (one being the best, six being the worst). Two individuals performed the rankings separately and the scores were averaged.

A taste test was also undertaken with harvested potatoes and carrots. Approximately 5 lbs of potatoes and 10 carrots were selected; carrots were peeled, cut into uniform wedges and served raw while potatoes were baked and served with skins. Varieties were randomly assigned a letter that only the test administrator was aware of and participants were asked to rank the varieties based on two variables: taste and color/texture.

Statistical analysis of the various parameters was performed by either mixed model ANOVA, with block as a random factor, or one-way ANOVA. Fisher’s LSD was calculated to describe differences between varietal means ($\alpha = 0.05$). Least significant difference values cannot meaningfully be reported for transformed data, so where data transformation was necessary to homogenize variances, significant differences between groups are reported using letter groups.

RESULTS

Growing Conditions

The 2008 growing season was characterized by extreme drought, with only 6.41 inches of precipitation occurring from the first of the year until trial harvest (Fig. 1). Of this amount, 5.43 in. fell over the period from May 14 to August 29. Average growing season temperatures were below normal by 1°F in May and 2°F in June, while average temperatures were 4° and 3° above average in July and August (Fig. 2). These higher average temperatures, which were illustrated by the fact that the temperature exceeded 90°F on 24 days of the season, combined with the extremely dry conditions, imposed severe stress on crops later in the season.

Carrots

General varietal characteristics of the types grown in this study are as follows: Hercules is a mid-season carrot with thick, tapered roots, Napoli is a Nantes type with blunt roots of average length, and

Nectar a full-season carrot similar to Negovia, but with slightly longer tapering roots sometimes grown for processing. Nelson is a commonly grown Nantes type that possesses short, blunt roots and is often harvested as a baby. Mokum is another early season carrot, while Sugarsnax 54 is a full-season carrot that produces long, slender roots.

Carrot yields were very low due to extreme drought (Table 2). The supplementary water applied undoubtedly improved yield to some extent, but not to a level that could be considered commercially competitive. Yields in the current trial ranged from 5191 kg/ha for Sugarsnax 54 to 8017 kg/ha for Hercules, while United States average commercial carrot yields in 2008 averaged approximately 15,000 kg/ha for fresh and 23,000 kg/ha for processing carrots (NASS). Overall, no significant differences in yield between varieties were observable, although Hercules and Napoli performed substantially better than the other four varieties, indicating some resistance to the dry conditions.

Significant differences in root length and diameter were observed between varieties. Sugarsnax 54 possessed the longest roots, with an average length of 17.8 cm. This is to be expected as this variety is known for its long roots. In fact, the varietal standard length of Sugarsnax 54 is 22 to 23 cm. Hercules, Napoli and Nectar had intermediate lengths, while Nelson and Mokum had the shorter observed lengths, averaging 12.5 and 13.7 cm, respectively. Hercules had the thickest roots, with diameter averaging 3.1 cm, Napoli and Nectar were intermediate, and Sugarsnax 54, Mokum and Nelson had the smallest diameters.

In terms of visual rankings, Hercules consistently ranked the highest and Sugarsnax 54 the lowest, although significant differences were not always observed between varieties. In the “condition of root” category, for instance, varieties did not differ significantly. In the other categories, however, Hercules appeal was demonstrated. In the “uniformity” category, Mokum and Nectar joined Hercules in having the most consist root structure, while in the “true to type” category Napoli, along with Hercules, had the highest ranking. In terms of the “visual appeal” and “size” categories, Hercules, Napoli, Nectar and Mokum had the highest rankings. Other than Sugarsnax 54, Nelson also consistently ranked poorly, and whereas Sugarsnax 54 tended to be branched, irregular and spindly, Nelson tended to be the most diminutive and least robust variety in the trial.

Taste tests did not indicate a distinct preference for any one variety, although Napoli ranked highest and Sugarsnax 54 the lowest. Analogously, in the color/texture category no clear winner emerged,

although in this category Napoli again ranked highest and Nelson the lowest.

These results indicate that Hercules and Napoli may have some potential for production in the region, given their relatively high yield, visual ranking scores, and in the case of Napoli, taste preference. Sugarsnax 54, on the other hand, was a uniformly poor performer in all categories.

Potatoes

Of the five varieties screened in this study, Gold Rush is an early, white-fleshed russet type, while Red Gold has a thinner reddish skin, yellow flesh and is often used as a new potato. Yukon Gold possesses golden flesh and the waxier skin of a boiler. Superior is medium maturing white and Russian Banana is a specialty potato that produces many small, ellipsoid tubers which possess a thin waxy skin that withstands boiling.

Potato yields were similar (approximately 10 to 13,000 lb/ac) for all varieties except Russian Banana, which differed significantly from all other varieties and yielded only 1357 lb/ac (Table 3). The low yields of this variety are likely due in some part to its late flowering date, indicating that a longer season may be required for this variety than can be expected in western North Dakota. Average flowering dates for the other varieties ranged from July 3 for Superior to July 17 for Red Gold.

Photosynthetically active radiation below the potato leaf canopy did not differ between varieties (Fig. 3). Above canopy PAR, however, was always significantly greater than below, while overall PAR did not differ below or above canopy over the three dates.

Volumetric soil water content under potatoes did not differ between varieties at either depth on any date, but soil moisture under all varieties was significantly greater at the 19 in. depth than at the 3 in. depth on every date (Fig. 4). Interestingly, overall soil moisture remained consistent over all three dates at both depths, with values between 20 and 25% at the 3 in. depth and between 36 and 38% at the 19 in. depth. This indicates that no significant decline in water content occurred as the season progressed, even though extremely dry conditions were extent. This is not an entirely surprising observation at the 19 in. depth, given the relative resistance of the lower soil profiles to moisture depletion, but the fact that moisture remained consistent at a 3 in. depth is unexpected. Although soil samples were not taken as part of this study, it can be presumed that soil physical properties had much to do with this phenomenon.

A soils capacity for water storage is influenced by its structure and organic matter content.

Generally, a sandy, coarser textured soil has larger, more continuous soil pores and therefore a higher hydraulic conductivity. This translates into a diminished water holding capacity compared with finer textured soils. However, good soil structure and the presence of water stable aggregates can aid in soil water retention by providing a large amount of total pore space while concurrently slowing downward water movement and remaining resistant to erosion. Aggregate stability, in turn, is directly related to soil organic matter content (Brady and Weil, 1999). Soil organic matter is extremely important to water holding capacity in soil not only because it enhances aggregate stability, but also because it directly absorbs and stores water. While the soil at this location is relatively coarse textured, moisture content was maintained at approximately 20-25% at the 3 in. depth late into the season, translating to approximately 1/4 to 1/3 in. of available water according to government estimates (NRCS). The retention of this amount of water could very well be due to the positive effects of substantial organic matter content in the upper soil horizons as a result of historic no-till management. While the specific depth to which the potatoes were able to access water was not determined, it can be assumed that the ability of the upper soil profile to retain water was integral in guarding against permanent wilting in the potato crop. Furthermore, water retention under potatoes was also surely enhanced to some degree by the reduced light penetration through the crop canopy, as indicated by the significantly lower PAR observations below the canopy as opposed to above.

Russian Banana was somewhat susceptible to insect pest damage, presumably leafhopper, while no other varieties sustained any insect damage. Verticillium was responsible for the death of two Red Gold plants, but did not spread to neighboring plants. The source of the infection was assumed to be the seed.

The taste test indicated no preference for any particular variety, although Red Gold ranked the highest and Superior and Gold Rush the lowest. In terms of texture and color, Red Gold and Gold Rush ranked the highest and Superior the lowest, although no statistically significant difference in scores was discernable.

Sweet Corn

Eight sweet corn varieties were included in this trial. The Xtra Tender varieties are supersweet (*sh2*) types, while all other are sugary enhanced (*se*). As for maturity, Spring Treat is an early season variety, Sugar Pearl, Luscious and Xtra Tender 272A are mid-season varieties and the remainders are generally recognized to be full-season varieties.

Of the three vegetable crops grown in 2008, sweet corn suffered the most from the dry conditions. Early season vigor ratings were most favorable for Spring Treat (Table 4). Xtra Tender 378A followed Spring Treat in the rankings, which is somewhat surprising considering the tendency of *sh2* varieties for reduced vigor in cooler soils. Luscious and Xtra Tender 277A, on the other hand, received the lowest scores. Interestingly, even though Luscious received a low early season vigor rating, it had the second earliest average date of tasseling, July 30, with only Spring Treat having an earlier tasseling date, July 24.

Sweet corn yields were very low. Sugar Pearl had the highest overall yields, averaging 3543 kg/ha, while Brocade and Xtra Tender 378A and 277A had the lowest yields. Additionally, actual marketable yield was markedly reduced in all varieties due mainly to arrested kernel development and uneven fill. On average, only about 25 to 30% of harvested ears were deemed of market quality, with Sugar Pearl producing the highest number of marketable ears, at 2133 per acre. Although large variability did not allow for any statistically significant differences to be observed in number of marketable ears, the variety producing the next greatest number was Xtra Tender 275A, with 960 ears/acre. One variety, Brocade, produced ears deemed marketable at all.

Given the dry conditions, plant heights of all varieties were low, with Sugar Pearl producing the tallest plants at 111 cm, although Luscious, Brocade and Xtra Tender 275A did not differ significantly in height from Sugar Pearl. Spring Treat was the shortest variety, with plants averaging only 78.1 cm tall.

Ear lengths were relatively uniform between varieties, averaging 18.1 cm, except for Spring Treat, which had significantly shorter cobs, measuring only 14.1 cm on average. In terms of ear width, Luscious produced the thickest ears, averaging 4.4 cm, while Brocade, Spring Treat, Sugar Pearl and Xtra Tender 277A produced the lowest average ear widths, averaging between 3.6 and 3.8 cm. Xtra Tender 277A and 378A had the greatest number of kernel rows/ear with 17. Spring Treat had the lowest with only 10. In the case of Spring Treat, and to a lesser extent in the other varieties, many ears contained unfertilized or aborted kernels and high variability in the fill pattern within the ear. Number of kernel rows is highly dependent on climatic and fertility conditions prior to and during silking, while stressful conditions later in the season can lead to aborted and unfilled kernels. It is assumed that the extremely variable kernel fill (and reduced ear length in Spring Treat) was attributable to the dry conditions in 2008.

CONCLUSION

Sweet corn was the most negatively impacted crop, but one variety, Sugar Pearl, did stand out as having relatively greater resistance to drought, even though its early season vigor was somewhat impaired. Sugar Pearl produced substantially more marketable ears than any other variety, although still yielding well below what could be considered economically viable. Nonetheless, this variety has been identified as having some potential for region and will be screened further in future years, as will the other varieties involved.

The other two vegetables screened, carrots and potatoes performed somewhat better overall than sweet corn. These vegetables are root or tuberous crops, which may have spared them somewhat from the most extreme effects of the drought. Still, yields were low in both crops. Carrots received minimal supplemental water, which undoubtedly boosted yields, but not to the level of average commercial yields. The Hercules carrot had the highest yield, although not significantly different from any other, and consistently ranked high in the visually assessed categories. Napoli also had a relatively favorable yield and performed adequately in the visual ranking, although uniformity seemed to be a slight issue for this variety. This variety also garnered the highest ratings in the taste test, although again, no statistical differences could be discern between varieties. The performance of these two varieties, Hercules and Napoli, indicate that they may have some drought resistance and therefore potential for the region.

These varieties will be screened further to assess long term performance. The Sugarsnax 54 variety, on the other hand, stood out for its poor performance, in terms of yield, visual qualities and taste.

As stated, potato yields were low, although no plants succumbed to drought or heat stress, indicating that sufficient water was retained in the soil to allow for normal development, a conclusion further substantiated by soil moisture measurements. Superior, the earliest flowering variety, had the highest yield (although not significantly greater than any other), but ranked low in the taste test. On the other hand, the second highest yielding variety, Red Gold, performed well on the taste test, illustrating potential interest from consumers.

As stated several times previously, the biggest factor affecting vegetable performance in 2008 was the extremely dry conditions. Yields of all crops suffered greatly, but nonetheless, the data obtained proved useful in assessing the response of the utilized varieties to extreme climatic conditions. One way to alleviate some water and drought stress in the future may include experimenting with mulches or no-till seeding methods, both which are known to increase water infiltration and reduce evaporation from the soil surface. Overall, the extension of these trials into future years will provide further insight into the best variety choices for the region, and hopefully spur interest in vegetable production in the region, whether for personal use or for commercial applications.

Table 1. Vegetable crop varieties used in the experiment.

Sweet Corn	Carrots	Potatoes
Brocade	Hercules	Gold Rush
Luscious	Mokum	Red Gold
Spring Treat	Napoli	Russian Banana
Sugar Pearl	Nectar	Superior
Xtra Tender 272A	Nelson	Yukon Gold
Xtra Tender 275A	Sugarsnax 54	
Xtra Tender 277A		
Xtra Tender 378A		

Table 2. Characteristics of the six carrot varieties included in the present study.

Variety	Length	Diameter	Yield	Visual Rankings†				Taste Test		
				Condition of root	Uniformity	True to Type	Visual Appeal	Size	Taste	Texture/Color
	—— cm ——		kg/ha							
Hercules	14.4	3.1	8017	2.5	2.3	1.8	2.3	2.5	3.00	3.50
Napoli	15.6	2.6	7688	3.1	4.1	2.9	2.8	3.0	2.00	2.30
Nelson	12.5	1.8	5448	3.9	3.9	3.9	3.8	4.5	4.00	4.50
Nectar	15.4	2.4	5356	4.0	3.4	3.6	3.0	3.0	3.75	3.80
Mokum	13.7	1.9	5219	3.1	2.4	3.6	3.6	3.0	3.80	3.30
Sugarsnax 54	17.8	2.1	5191	4.4	5.0	4.9	5.6	5.0	4.50	3.80
Mean	14.9	2.3	6153	3.5	3.5	3.4	3.5	3.5	3.51	3.53
CV (%)	29.2	33.1	38	49.3	49.3	49.1	49.3	28.6	49.79	49.79
LSD ($\alpha = 0.05$)	1.8	0.3	NS	NS	1.5	1.5	1.4	2.0	NS	NS
<i>P</i>	0.0001	0.0001	0.1460	0.2590	0.0048	0.0040	0.0014	0.0121	0.433	0.6504

†Visual and taste test rankings are relative, with 1 being the highest ranking and 6 being the lowest.

Table 3. Characteristics of the five potato varieties included in the present study.

Variety	1st flower	Yield lb/ac	Taste Test†	
			Taste	Texture/Color
Superior	July 3	12770	3.50	4.25
Red Gold	July 17	12145	2.50	2.25
Gold Rush	July 10	10896	3.50	2.25
Yukon Gold	July 14	10078	2.75	3.00
Russian Banana	July 29	1357	2.75	3.25
Mean	July 16	7063	3.13	3.75
CV (%)	5	58	48.37	48.37
LSD ($\alpha = 0.05$)		3967	NS	NS
<i>P</i>		0.0001	0.8334	0.2745

†Taste test rankings are relative, with 1 being the highest ranking and 6 being the lowest.

Table 4. Characteristics of the eight sweet corn varieties included in the present study.

Variety	Vigor†	Tassel Date	Ears	Marketable Ears	Yield‡	Plant Height	Ear Length	Ear Diameter	Kernel Rows
			no./ac		kg/ha		cm		
Spring Treat	0.75	July 24	5733	751	1961b	78c	14.1b	3.6c	10d
Xtra Tender 378A	0.25	Aug 5	1445	285	788cd	102b	18.7a	4.0ab	17a
Xtra Tender 275A	-0.25	Aug 4	2942	960	1619bc	106ab	17.9a	4.1a	16b
Sugar Pearl	-0.75	July 31	5463	2133	3543a	111a	18.4a	3.8bc	15c
Xtra Tender 272A	-0.75	Aug 2	2153	680	1272bc	93b	16.6a	4.1a	16b
Brocade	-0.75	Aug 1	846	0	582cd	109a	18.9a	3.8bc	14c
Xtra Tender 277A	-1.00	Aug 4	603	490	417d	98b	18.9a	3.7bc	17a
Luscious	-1.00	July 30	2541	777	1719bc	105ab	17.2a	4.4a	16b
Mean	-0.44	1-Aug	2716	757	1488	100	18	4	15
CV (%)	173.56	5	92	104	93.00	12.9	12.0	10.6	15
LSD ($\alpha = 0.05$)	0.76	–	2769	NS	–	–	–	–	–
<i>P</i>	0.0004	–	0.0045	0.0985	0.0087	0.0005	0.0011	0.0503	0.0001

†Vigor ratings are on a scale of -1 (below average) to +1 (above average).

‡Where data transformations were necessary LSD is not reported. Values within each column followed by the same letter do not differ significantly when $\alpha = 0.05$.

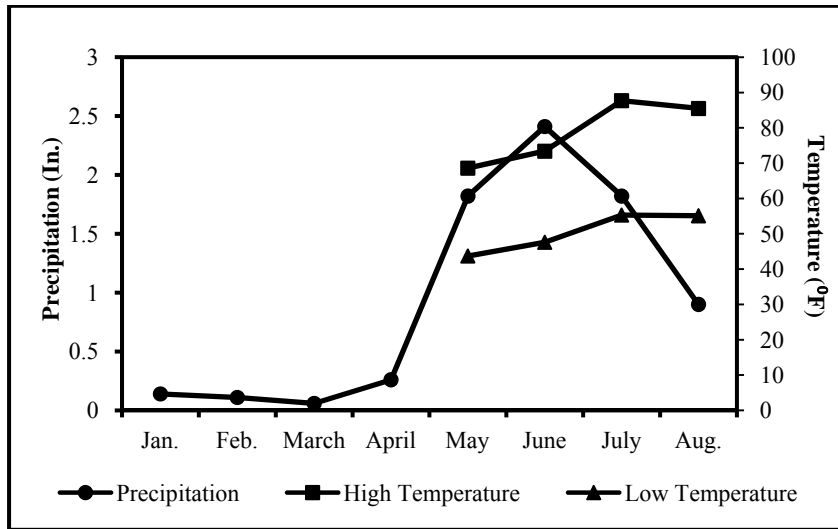


Figure 1. Average monthly precipitation and high and low temperatures for 2008.

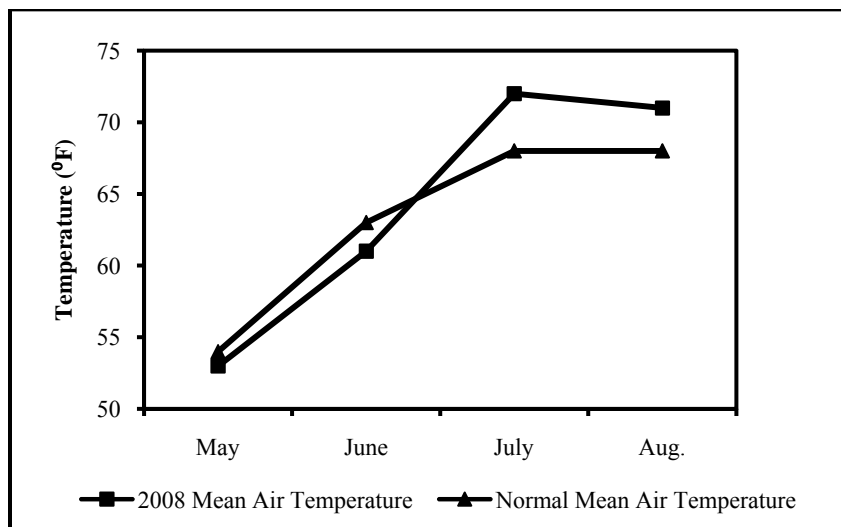


Figure 2. Mean monthly air temperatures for the 2008 growing season and annual averages for the period.

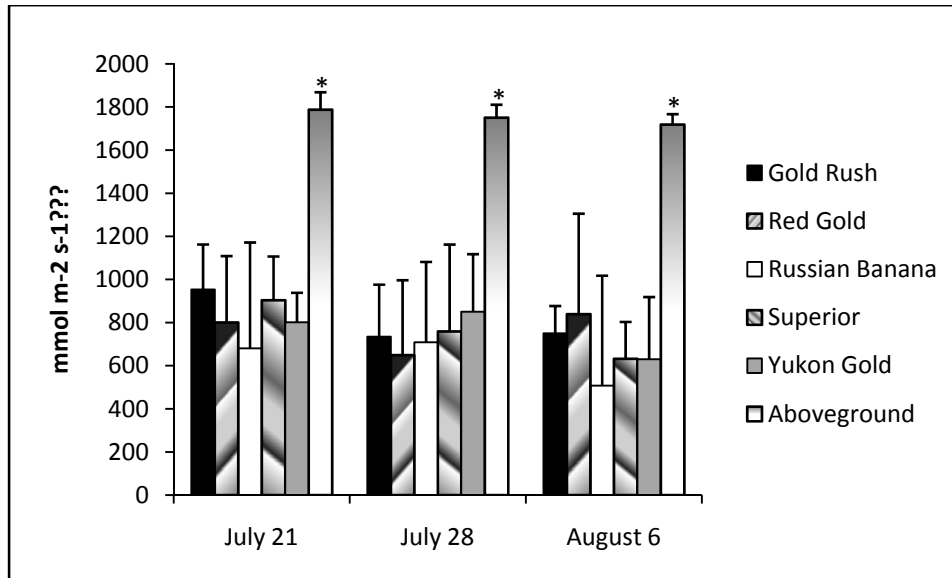


Figure 3. Photosynthetically active radiation as measured in potatoes on the three dates indicated. Asterisks denote significantly greater above canopy PAR compared to all others on each date.

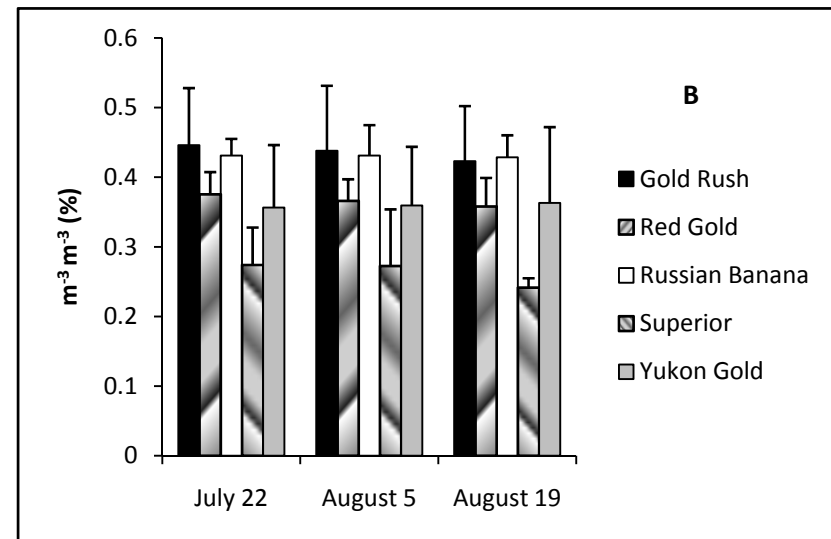
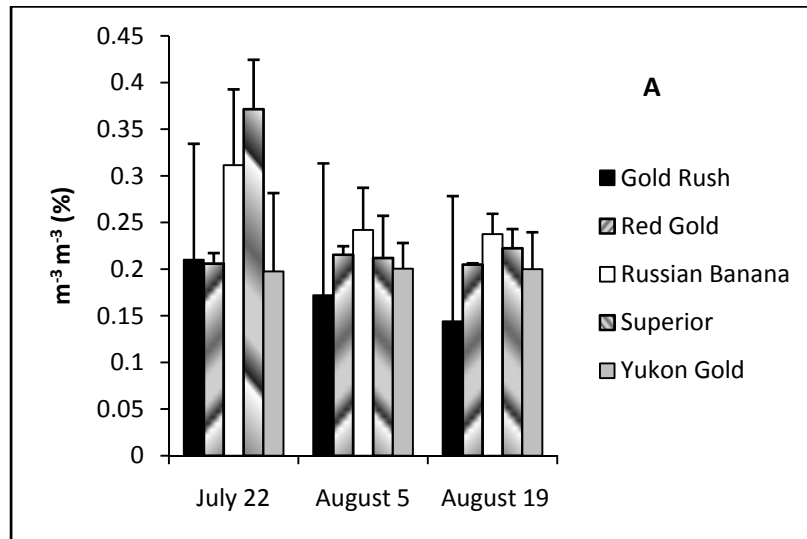


Figure 4. Volumetric water content at the (A) 3 inch and (B) 19 inch depth as measured in potatoes on the three dates indicated.

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