Performance of Heat-tolerant Lettuce Cultivars in Southern New Mexico in 2020–21

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Abstract. **Lettuce (*Lactuca sativa*) is a high-value crop cultivated worldwide. Harvested lettuce acreage in New Mexico, USA, trails the leading lettuce production states (California, Arizona), but growers in New Mexico are interested in expanding their production. For New Mexico farmers to increase lettuce production to reach new markets, information on heat-tolerant cultivar performance is needed. This study was conducted to evaluate six lettuce cultivars described as heat tolerant by seed suppliers or other sources. In 2020 and 2021, we assessed two butterhead types, 'Anuenue' and 'Mikola RG10'; two green leaf types, 'Muir' and 'Tropicana'; and two romaine types, 'Parris Island Cos' and 'Sparx', in the Jose Fernandez Garden at the New Mexico State University Heritage Farm in Las Cruces, NM. To determine which cultivars and types of lettuce are better suited for southern New Mexico, we measured these variables: marketable harvest weight, number of days from transplant to first bolt, and number of days from transplant to 50% bolted. In 2020, 'Sparx', a romaine-type lettuce, had, on average, 32% higher yield compared with the other lettuce types. In 2021 both romaine-type cultivars, Sparx and Parris Island Cos, produced 19% more marketable yield than the other lettuce cultivars. In 2020, 'Sparx' was the last to bolt and to reach the 50% bolted stage, whereas in 2021 'Mikola RG10' and 'Muir' were the last cultivars to bolt and reach the 50% bolted stage. These results suggest that 'Sparx' would be a good potential candidate for farmers in southern New Mexico. 'Mikola RG10' and 'Muir', butterhead and green leaf type, respectively, demonstrated slower bolting in 2021, indicating they may be useful cultivars for extending lettuce harvest in New Mexico.**

Cultivated lettuce (*Latuca sativa*) acreage has increased by 52% since 2012 throughout New Mexico, USA [US Department of Agriculture, National Agricultural Statistics Service (USDA-NASS) 2017]. Although the cultivated lettuce acreage in New Mexico is far behind leading lettuce production states California and Arizona (USDA-NASS 2022), New Mexico growers are interested in expanding into lettuce production with the aim of reaching new markets (Havlik et al. 2022). Lettuce is a cool season crop that achieves greatest growth under diurnal air temperatures of 73 °F maximum and 45 °F minimum (Smith et al. 2011). To achieve this temperature range in New Mexico, typically December through February are the months recommended for planting lettuce (Walker 2021). Yet the past decade has been the warmest on record, with increasing hot days and warms nights during the lettuce planting period (National Oceanic and Atmospheric Administration 2022). In the southern part of state, lettuce is usually grown as a rotational crop with other vegetables crops during the winter and early spring (Sanogo et al. 2019) and sold in larger markets. Growers are eager to find lettuce cultivars with sustained production in warmer temperatures.

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Temperature is one of the main factors affecting the germination and growth rate of lettuce (Wien 1997). Higher temperatures often reduce lettuce yield and cause physiological disorders such as premature bolting, tipburn, and ribbiness (Lafta et al. 2017). One of the main methods of overcoming temperature limitations for lettuce production is cultivar selection (Wien 1997). Seed companies have many listed heat-tolerant lettuce cultivars, some of which have been evaluated in different locations (Dufault et al. 2009; Kolbe et al. 2019; Lafta et al. 2021) and many cultivars have been found to be heat tolerant in specific locations. Heat tolerance is the capacity of plants to function and remain productive under high temperature stress (Lafta et al. 2017). The two basic steps to achieving successful lettuce production in higher temperatures in specific climates are 1) determine which cultivars are more heat tolerant in that distinct climate and 2) assess which planting dates are best suited without negatively affecting production.

In this study, we initiated work on step 1: we evaluated six lettuce types for their tolerance to higher temperatures in southern New Mexico. This initial field screening included cultivars marketed as being heat tolerant and/or slow bolting. The results from this 2-year trial provide information about heat-tolerant lettuce performance in southern New Mexico to help growers with cultivar selection.

Materials and methods

In 2020 and 2021, six lettuce cultivars advertised as heat tolerant were selected, two butterhead cultivars, Anuenue (Wild Garden Seed, Philomath, OR, USA) and Mikola RG10 (Brad Tonnessen, Las Cruces, NM, USA); two green leaf-type cultivars, Muir (Johnny's Selected Seeds, Fairfield, ME, USA) and Tropicana (Johnny's Selected Seeds); and two romaine

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
0.1242	gal/100 ft	$L \cdot m^{-1}$	8.0520
2.54	inch(es)	cm	0.3937
0.4536	lb	kg	2.2046
6.8948	psi	kPa	0.1450
2.2417	ton(s)/acre	$Mg \cdot ha^{-1}$	0.4461
(°F − 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

cultivars, Parris Island Cos (Baker Creek Heirloom Seed Co., Mansfield, MO, USA) and Sparx (Johnny's Selected Seeds). These cultivars were grown at the Jose Fernandez Garden at the New Mexico State University Heritage Farm in Las Cruces, NM, USA (lat. 32°N, long. 106°W, elevation 3890 ft). Transplants were planted in a greenhouse at the Fabian Garcia Research Center in Las Cruces, NM, USA, on 23 Mar 2020 and 26 Mar 2021 and transplanted into the field on 8 May 2020 and 7 May 2021, respectively. Transplants were hand planted in a single row on a 20-ft-long by 3.3-ft-wide bed with 12-inch between-plant spacing allowing 20 plants per plot with a single line of drip irrigation tubing [12 inches emitter spacing, 0.23 gal/100 ft per hour at 10.0 psi (Netafim, Fresno, CA, USA)] placed in the center of each bed. Composite soil tests were completed before each season (Ward Laboratories, Kearney, NE, USA) on 15 Jan 2020 and 17 Jan 2021. Pelletized chicken manure with 4N–3P–2K (Chicken Manure Pellets; Crop Fertility Services, Cokato, MN, USA) was applied preplant in bands down the middle of the beds at 1.8 tons/acre to meet the nutrient demands of the lettuce throughout the season (Bottoms et al. 2012). During the 2020 season, plastic mulch from another study blew onto the lettuce plots for one weekend in May. This slightly delayed the growth of all the lettuce plots in 2020 and the 'Mikola RG10' and 'Muir' plots were situated in a way where the plastic mulch was heavier on half of the plots, so some seedlings died. Remaining seedlings were harvested for yield weights, therefore bolting assessments were not possible for these cultivars in 2020. The trial was set up in a randomized complete block design with three replications of each cultivar. The trial field was hand weeded twice per week for the entirety of each season, and plots were drip irrigated according to best management guidelines (Kerns et al. 2022) at 38 to 50 inches of water per season. The middle 10 ft of each plot were hand harvested at maturity, ~30 d after initial heading started on 17 Jun 2020 and 15 Jun 2021. The total weight of 10 marketable lettuce heads were measured after harvest. Bolting assessments were made weekly and occurred until 50% of the lettuce in each plot had bolted. The bolting measurements continued past harvest, so the additional sections of each plot that were not harvested (5 ft in the beginning and 5 ft at the end of the plot) were counted in the bolting assessments.

Statistical analysis. Analysis of variance was completed using statistical software (SAS ver. 9.4; SAS Institute Inc., Cary, NC, USA) to determine the effect of cultivar on marketable harvest weight, number of days from transplant to first bolt, and number of days from transplant to 50% bolted. Initially, we used two-way of analysis of variance, with cultivar and year in the model. Year was statistically significant at $\alpha \leq 0.05$, and therefore, we conducted subsequent analyses with data separated by year. Cultivar was also statistically significant between years, so cultivars were compared separately by year. The means for each response variable measured within a cultivar were separated using Tukey–Kramer tests ($\alpha \leq 0.05$).

Results and discussion

New Mexico growers want to expand their lettuce market, and this can be done by cultivating heat-tolerant cultivars that are suitable for their climate. Air temperatures and accumulated precipitation was similar in seasons 1 and 2 [Table 1 (New Mexico Climate Center 2020, 2021)]. The recommended growing temperatures for lettuce are diurnal air temperatures of 73 °F maximum and 45 °F minimum (Smith et al. 2011). During both of our growing seasons, the temperatures exceeded the maximum air daytime growing temperatures of lettuce by an average of 19.3 °F in 2020 and 18.3 °F in 2021. These high temperatures provided a suitable climate to assess the heat tolerance of the lettuce cultivars in our trials (Wien 1997). In both growing seasons, the lettuce seedlings were transplanted in the field in May, 2 months after the latest recommended planting date (Walker 2021). The delayed planting date made certain the lettuce grew in higher temperatures and that our results could translate into the most heat-tolerant cultivars for the southern New Mexico climate.

Each lettuce type has a different head growth pattern: butterhead-type and green leaf-type lettuce cultivars have loosely arranged leaves, whereas romaine-type lettuce heads have leaves that are tightly positioned together (Wien 1997). These structural differences between lettuce types can lead to a difference in head weight based on lettuce type. Consequently, the objective of this cultivar trial was to measure how each lettuce type and cultivar performed in the southern New Mexico climate. Thus, we compared various lettuce types to gather initial productivity information based first on lettuce type and then by cultivar.

In both the 2020 and 2021 growing seasons, romaine-type lettuce cultivars had consistently high yields, although they were not statistically different from other lettuce types (Table 2). We attribute the lower yield weights of all cultivars in 2020 (Table 2) to the plastic mulch that blew over the lettuce plots for 1 weekend in May. The overall yields were higher in 2021; we still analyzed 2020 data because all plots were influenced by the mulch, and we were able to harvest 10 heads of lettuce from each plot. In 2020, 'Sparx', a romaine-type lettuce, had on average 32% more overall yield compared with the other lettuce types. In 2021, both romaine-type cultivars, Sparx and Parris Island Cos, were top performers producing on average 19% more marketable yield than the other lettuce cultivars. Typically romaine lettuce is not considered to be heat tolerant, but some romaine cultivars have exhibited better yields

Table 1. Monthly averages of daily maximum, mean, and minimum temperatures and accumulated precipitation during the field trials in 2020 and 2021 in the Jose Fernandez Garden at the New Mexico State University Heritage Farm, Las Cruces, NM, USA.

Yr[i]	Month	Maximum air temp (°F)[ii]	Mean air temp (°F)	Minimum air temp (°F)	Precipitation (inch)[ii]
2020	May	90.7	75.3	57.5	0
	June	97.8	81.5	64.5	0.24
2021	May	89.3	74.2	56.1	0
	June	97.2	82.4	65.2	0

[i] New Mexico Climate Center (2020, 2021).
[ii] (°F – 32) ÷ 1.8 = °C, 1 inch = 2.54 cm.

Table 2. Average marketable lettuce head weight, time to first bolt, and time to 50% bolted by cultivar for 2020 and 2021 growing seasons.

		2020			2021		
Cultivar[i]	Lettuce type[ii]	Marketable wt (kg)[iii]	Time to first bolt (d)[iv]	Time to 50% bolted (d)[v]	Marketable wt (kg)	Time to first bolt (d)	Time to 50% bolted (d)
Anuenue	Butterhead	2.0 ab[vi]	39 b	45 b	6.0 ab	40 c	49 bc
Mikola RG10	Butterhead	1.3 b	ND[vii]	ND	4.5 b	54 a	57 a
Muir	Green leaf	1.6 ab	ND	ND	6.2 ab	55 a	57 a
Tropicana	Green leaf	2.1 ab	39 b	47 ab	5.9 ab	42 c	47 c
Parris Island Cos	Romaine	2.1 ab	40 b	46 b	7.0 a	41 c	50 bc
Sparx	Romaine	2.4 a	45 a	49 a	6.4 a	48 b	53 b

[i] 2020 growing season 8 May 2020 transplanted in field, 17 Jun 2020 lettuce harvested and data collected; 2021 growing season 5 May 2021 transplanted in field, 15 Jun 2021 lettuce harvested and data collected.
[ii] Lettuce groups based on plant form and main use.
[iii] Marketable weight from 10 harvested lettuce heads, average from three replicated plots (N = 3); 1 kg = 2.2046 lb.
[iv] Days between transplanting in field to first bolt in plot, average from three replicated plots.
[v] Days between transplanting in field to 50% bolted in each plot, average from three replicated plots.
[vi] Means with the same letter within columns are not significantly different via Tukey–Kramer Grouping at $\alpha \leq 0.05$.
[vii] ND = bolting data were not measured due to field damage to bolting assessment sample areas in these plots.

than the average in warmer climates (Dufault et al. 2009).

In 2020, the average marketable weight of the romaine lettuce from our trials (0.2 kg per head of romaine lettuce) was less than half the average weight of romaine lettuce harvested in California (0.58 kg per head of romaine lettuce; Mayberry 2000). In 2021, however, the average weight of the romaine lettuce in our trial (0.6 kg per head of romaine lettuce) was slightly greater than the California average, demonstrating that the romaine-type lettuce we grew in 2021 was comparable to the romaine lettuce harvested in California. Illustrating that southern New Mexico lettuce producers can become possible contenders on the national lettuce market.

Bolting, when lettuce transitions from vegetative growth to reproductive growth, is promoted in lettuce when temperatures exceed 86 °F (Liu et al. 2020). After bolting occurs, the edible portion of lettuce can no longer be harvested. Early bolting could be related to a high sensitivity to increased temperature (Wien 1997) and is not a desirable trait for lettuce cultivation in warmer temperatures. In 2020, 'Sparx' (romaine-type lettuce) was the slowest to bolt (Table 2), whereas in 2021 'Mikola RG10' (butterhead-type lettuce) and 'Muir' (green leaf-type lettuce) took the longest time bolt of all of the cultivars tested. The fluctuations between lettuce types and cultivars we found in our time-to-bolt data has been corroborated by other studies (Kolbe et al. 2019; Lafta et al. 2017). Chen et al. (2011) found leaf-type lettuce to have greater genetic variation in response to heat stress, indicating additional leaf-type lettuce cultivars might have suitable heat tolerance in southern New Mexico. Lettuce bolting in southern New Mexico is an area where additional research needs to be done to draw conclusions about which cultivars have a tendency to bolt faster or slower and whether the bolting is related more to temperature increases or duration of daylength (Liu et al. 2020). It is advantageous for growers to have lettuce cultivars with an increased time to bolt so that they can rely on sustained production as temperatures rise.

Conclusions

This research trial is the first to identify optimal lettuce cultivars for the southern New Mexico region. The consistent high yield of romaine-type lettuce cultivar Sparx make it a suitable option for growers in southern New Mexico. 'Sparx' was productive into the warmer months of the summer, while 'Mikola RG10' (butterhead type) and 'Muir' (green leaf type), demonstrated slower bolting in 2021. These cultivar performance results offer an initial starting point for further research into appropriate planting dates for southern New Mexico lettuce growers.

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