THE INFLUENCE OF STORAGE ON THE PHYSIOLOGY AND PRODUCTIVITY OF KENNEBEC SEED POTATOES[1]

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ABSTRACT

Kennebec seed potatoes were stored in various atmospheres of O_2 and CO_2 at 32 and 41 F (0 and 5 C). Samples were removed every 6 weeks for measurement of bud and parenchyma tissue respiration, rate of ion loss from tissue sections and reducing sugar content. Potatoes remaining at the end of the storage period were warmed, cut and planted immediately in a randomized complete block design for yield evaluation.

Intact tuber respiratory rates were higher at 32 F than 41 F. Increasing CO_2 increased respiratory rates and decreasing O_2 decreased respiratory rates at both temperatures.

Decreasing O_2 concentration significantly decreased reducing sugar at both 32 and 41 F. Increasing CO_2 significantly increased reducing sugar at 41 F but not at 32 F.

Kennebec potatoes did not tolerate added CO_2 at 32 F but did survive 4% CO_2 at 41 F. Reducing oxygen decreased the tolerance to CO_2. The onset of carbon dioxide injury was not clearly evident from changes in bud and parenchyma tissue respiration or in loss of electrolytes from cut tissue sections. However, CO_2 accelerated tuber breakdown by unidentified *Fusarium Spp.*

No significant differences in yield were observed between treatments that survived the storage period.

RESUMEN

Semillas de papa Kennebec fueron almacenadas a varias atmosferes de oxigeno (O_2) y dioxido de carbono (CO_2) a 32 y 41 grados Farengei (0 y 5 centigrados). Cada seis semanas fueron tomadas muestras para medis la respiración de los tejidos en las yemas y en el paran quima, la rata de pérdida de iones de los tejidos sexcionados y la reducio del contemido de azúcar. Las papas que quedaron hasta el final del periodo de almacenzje fueron calentadas, costadas y sembradas immediatamente, usando el diseño de bloques completamente al azar, para evaluar la produción.

Ratas de no alteración en la respiración de los tuberculos fueron más altas a 32 grados Farengeit que a 41 grados Farengeit. Aumento de CO_2 aumenta la rata de respiración y disminución de O_2 disminuye la rata de respiración a ambar temperaturas. Significante disminución de la concentración de oxígeno disminujo la reducción de azúcar a ambas temperaturas 32 y 41 F. Aumento significativo de CO_2 aumentó la reducción de azrícar a 41 F pero no a 32 F.

Papa Kennebec no tolenó la adición de CO_2 a 32 F pero sobre vivió

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a la adicion de 4% de CO_2 a 41 FF. La disminución de oxígeno disminuyo la tolerancia as CO_2. Los naños producidos por el ataque del dioxido de carbono no fueron claramente evidente debidos ac ambios en el tejido de la yema o el paranquima, o perdida de electolitos del tejido de les secciones cortadas. Sin embargo, el CO_2 acelera el deteríodo del tubérculo debido a un no identificado *Fusarium Spp.*

No observaron diferencias significantes en produción entre semillas que sobrevivieron al almacenaje.

This study evaluated the influence of storage temperature and atmosphere on the physiology and field performance of Kennebec seed potatoes. Our previously reported studies (3) showed that Russet Burbank seed potatoes stored at 39 F (2.6 C) in O_2 concentrations ranging from 2.5 to 21.0% yielded similarly when compared in randomized field trials. However, seed potatoes receiving continuous forced air ventilation outyielded those from a nonforced air ventilated environment. In a later study (4) Russet Burbank seed potatoes were stored at 32 and 41 F and continuously ventilated with atmospheres varying in O_2 and CO_2 concentrations. Increasing Carbon dioxide resulted in either complete tuber breakdown during storage, increased decay of cut seed by unidentified *Fusarium Spp.* or by a yield reduction. Toxicity of CO_2 was increased at the lower storage temperature and lower oxygen concentrations.

Materials and Methods

Approximately 6 weeks after harvest certified Kennebec seed potatoes were placed in 25 liter sealed storage containers at 32 and 41 F. Atmospheres varying in O_2 and CO_2 concentrations were passed through the chambers at a rate of 10 liters per hour per 50 lbs of potatoes. Periodically during storage the following laboratory observations were made: (i) respiratory rates of intact tubers, ii) the ability of cut tuber sections to retain electrolytes when placed in distilled water, iii) rate of oxygen consumption at 68 F (20 C) by bud and parenchyma tissue sections, and iv) reducing sugar content. Except for the analyses of reducing sugar, the procedures followed were described previously (3, 4). Reducing sugar content was determined with the method of Hassid (2) by oxidation with potassium ferricyanide and titration with ceric sulfate.

In May, surviving seed potaoes were warmed at 68 F for various periods depending on sprout development. The seed was then cut into 2 to 3 oz. pieces just before planting. The productivity of the mother plants was evaluated in a randomized complete block field trial.

Results

Intact tuber respiration. A list of treatments and their influence on intact tuber respiration in given in Table 1. In the same atmosphere the respiratory rates were consistently lower at 41 F than at 32 F. At both temperatures, increasing carbon dioxide with air, 2% O_2 or 5% O_2, consistently increased tuber respiration and reducing oxygen slightly reduced respiration. The respiratory quotients remained close to 1.0. How-

TABLE 1.—*The influence of the storage atmosphere and temperature on tuber respiration.*

Storage atmosphere[2]	Respiratory rates and Quotients[1]					
	32 F			41 F		
	CO_2[3]	O_2[3]	RQ[4]	CO_2	O_2	RQ
Air	1.4	1.8	0.8	1.1	1.4	0.8
Air + 4% CO_2	2.2	2.4	0.9[5]	1.2	1.4	0.8
Air + 8% CO_2	2.7	2.8	1.0[5]	1.6	1.5	1.0[5]
Air + 12% CO_2	4.0	3.7	1.1[5]	2.4	2.6	0.9[5]
2% O_2	0.9	0.9	1.0	0.6	0.6	1.0
2% O_2 + 4% CO_2	1.1	1.1	1.0[5]	0.7	0.8	1.0
5% O_2	0.8	0.7	1.1	0.6	0.7	0.9
5% O_2 + 4% CO_2	1.5	1.6	0.9[5]	0.8	0.7	1.1
AVERAGE	1.8	1.9	0.9	1.1	1.2	0.9

[1]Values shown are averages of measurements made after the potatoes had been in storage 2 months.
[2]To compute the partial pressures of O_2 and CO_2 the barometric pressures at Fort Collins, Colorado is 632 mm Hg.
[3]Milliliters per kilogram hour.
[4]Respiratory quotient.
[5]These treatments did not survive the entire storage period.

ever, at 32 F the R.Q. increased slightly when CO_2 in the air was increased from 0 to 12%.

Bud and parenchyma tissue respiration. Parenchyma tissue respiration following both 32 and 41 F generally increased from 2 to 6 to 24 hours after cutting (Fig. 1). The magnitude of the difference with time after cutting depended on storage treatment and time. For example, respiratory rate differences between 2, 6, and 24 hours were large in December but small in May, see air and 4% CO_2 and certain other treatments at 32 F.

Following 32 F, bud respiration was higher than parenchyma tissue respiration but showed a similar pattern. However, following 41 F bud respiration increased rapidly in March or May while parenchyma respiration rate did not. When bud activity was suppressed at 41 F, eg. 2% O_2 and 4% CO_2, bud and parenchyma tissue respiration was similar.

Tissue respiration following storage in 8 and 12% CO_2 are not included in Fig. 1. During January tuber breadown began in these treatments. In December and January, however, respiratory rates following 8 and 12% CO_2 at 32 F resembled those following 4% CO_2. Tissue respiratory rates in December and January following 41 F storage in 8 and 12% CO_2 resembled those following 2% O_2 and 4% CO_2.

Reducing sugar content. Since reducing sugar content was obviously higher at 32 than at 41 F, separate statistical analyses were run for each temperature (Table 2). A highly significant decrease in reducing sugar was attributed to lower O_2 concentrations at 32 and 41 F. At 32 F, CO_2 had no effect on reducing sugar but effected a highly significant increase at 41 F. Sampling dates gave highly significant differences in reducing

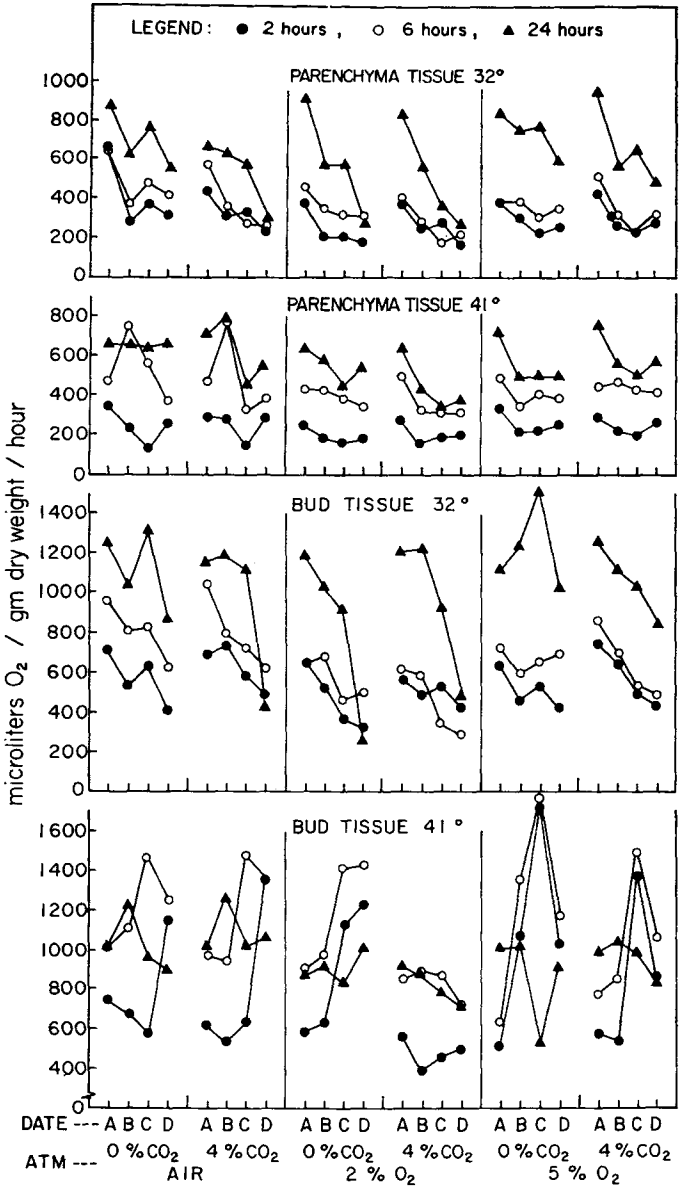

FIG. 1.—Influence of storage temperature, time and atmosphere on parenchyma and bud tissue respiration at 68 F 2, 6 and 24 hours after removal from storage and cutting. Date of observation: A-Dec. 4, B-Jan. 31, C-Mar. 13, D-May 1.

TABLE 2.—*Influence of storage temperature, time, oxygen and carbon dioxide concentration on the % reducing sugar based on fresh weight.*

	% Reducing sugar[1]								
	0% CO_2				4% CO_2				Combined O_2
Date	1/31	3/13	5/1	Ave	1/31	3/13	5/1	Ave	Average
% O_2									
	Storage temperature 32 F								
2	1.4	1.7	1.3	1.5	1.9	1.2	2.5	1.9	1.7
5	2.6	1.3	2.2	2.1	1.5	1.4	2.9	1.9	2.0
Air	2.9	3.3	2.8	3.0	1.7	3.3	3.2	2.7	2.9
Ave. CO_2	2.3	2.1	2.1	2.2	1.7	2.0	2.9	2.2	
	Storage temperature 41 F								
2	0.4	0.2	0.5	0.38	0.5	0.4	0.6	0.50	0.44
5	0.4	0.4	0.6	0.47	0.7	0.4	0.8	0.61	0.54
Air	0.5	0.5	0.8	0.62	0.8	0.4	0.9	0.68	0.65
Ave. CO_2	0.44	0.36	0.66	0.49	0.65	0.40	0.73	0.59	

[1]Each value is an average of 3 replications.

TABLE 3.—*Influence of storage temperature, time, oxygen and carbon dioxide concentration on the rate of ion leakage from cut tissue sections.*

	Micromohs per hour[1]										
	0% CO_2					4% CO_2					Combined O_2
Date	12/4	1/31	3/13	5/1	Ave.	12/4	1/31	3/13	5/1	Ave.	Average
% O_2											
	Storage temperature 32 F										
2	48	85	87	222	110	28	93	217	100	110	110
5	62	147	173	117	125	43	100	193	207	136	130
Air	148	158	193	200	175	58	150	180	277	166	171
Ave. CO_2	86	130	151	179	136	43	114	197	194	137	
	Storage temperature 41 F										
2	26	20	33	15	24	32	27	38	32	32	28
5	34	20	22	33	27	32	32	32	50	36	32
Air	32	28	20	50	33	27	27	32	33	30	31
Ave. CO_2	31	23	25	33	28	30	28	34	38	33	

[1]Each value is an average of 3 replications and is the increase in conductivity in micromhos per hour of distilled water containing tissue sections.

sugar content. The lowest sugar content occurred in March at 41 F. Reducing sugar increased with time at 32 F in 4% CO_2 but not in the absence of CO_2.

Retention of electrolytes by cut tissue sections. The rate of electrolyte loss from tissue sections was obviously more rapid following storage at 32 than 41 F (Table 3). Thus, the data were subjected to separate statistical analyses. Decreasing oxygen at 32 F gave a highly significant decrease in the rate of electrolyte loss. But, in 41 F oxygen had no effect.

No significant differences in the rate of electrolyte loss could be attributed to CO_2 at either 32 or 41 F.

Highly significant increases in the rate of electrolyte loss occurred with storage time at 32 F. No differences were attributable to storage time at 41 F. A highly significant interaction between CO_2 X sampling date occurred at 32 F. During the first two samplings, the rate of electrolyte loss was more rapid following storage in 0% CO_2 whereas loss was more rapid during the latter two samplings following 4% CO_2.

Stand, stem number and productivity. Kennebec potatoes stored in 4, 8 and 12% CO_2 at 32 F either decayed in storage or failed to produce plants. Potatoes survived 4% CO_2 at 41 F but did not survive 8 and 12% CO_2. Stand differences between surviving treatments were not significant. The percentage stand was generally excellent and ranged from 93 to 98%.

Stem number per plant ranged from 2.2 to 3.8 and the differences were significant. However, no significant effects could be attributed to storage temperature or oxygen level. Carbon dioxide level at 41 F exerted a highly significant influence on stem number. However, a highly significant interaction also existed between O_2 and CO_2.

Correlation analysis showed a highly significant correlation, $r = -0.81$, between stem number per plant and weight of tubers over 3 inches diameter produced per acre. The regression of number of tubers over 3″ per acre(y) on number of stems per plant(x) was determined to be: $y = 101 - 19.6x$.

The differences in total yield or tuber sizes between the surviving storage treatments were not significant.

Discussion

Kennebec potatoes were less tolerant of CO_2 in storage than we observed in prior studies with Russet Burbank (3, 4). However, the varieties were similar in respect to the following: i) tuber respiration, ii) higher respiratory rates at 32 than 41 F, iii) increase in respiratory rates due to CO_2 at both 32 and 41 F, iv) bud and parenchyma tissue respiratory patterns following comparable storage treatments, and v) rate of electrolyte loss from tissue sections.

Although the above observations failed to show a difference between Kennebec and Russet Burbank, Kennebec was more susceptible to CO_2 injury. Kennebec did not tolerate 4% CO_2 at 32 F and 8% CO_2 at 41 F. In contrast, Russet Burbank was not injured by 4% CO_2 at 32 F nor 8% CO_2 at 41 F. Yield was good following these treatments.

Previously, a nonlethal effect of CO_2 on bud development in Russet Burbank resulted in reduced productivity without any reduction in stand (4). However, with Kennebec no differences in productivity existed between surviving treatments. Possibly differential warming of Kennebec seed at 68 F, depending on sprout development, eliminated storage treatment differences.

Increasing CO_2 with air, 2% O_2 or 5% O_2, significantly increased reducing sugar content at 41 F. This agrees with Butchbaker et. al. (1). At 32 F, there was no effect of CO_2 on reducing sugar. Decreasing O_2 significantly decreased reducing sugar content at both 32 and 41 F. This does not agree with Butchbaker et al. (1) who reported no decrease in reducing sugar with reduced oxygen.

The increase in the respiratory rate of cut tissue sections from 2 to 24 hours after cutting is frequently referred to as the wound respiratory response. Considerable research has been done to determine the physiological basis for this response. This study clearly shows that the magnitude or even the presence of a respiratory increase is determined by storage atmosphere and storage time.

In this study, Kennebec seed potatoes yielded well following storage in 2% O_2. In prior studies, Russett Burbank seed also yielded well following low oxygen storage (3, 4). This suggests that O_2 is not a critical factor in seed storage unless anaerbiosis results in blackheart.

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