DAV International Journal of Science

SUGAR CONTENT AND STORAGE LOSSES OF POTATO (*SOLANUM TUBEROSUM* L.) AS INFLUENCED BY PLANTING TIME AND FERTILIZER DOSES UNDER AMBIENT CONDITIONS

Sandhu A.S.*, Sharma S.P*, Bhutani R.D., and Khurana S.C.****
*Department of Vegetable Crops, PAU, Ludhiana-141004, Punjab, India
**Department of Vegetable crops, CCS HAU, Hisar-125004, Haryana, India.
(E-mail address: Sharma S.P- sps145@gmail.com)

ABSTRACT
Potato cultivar 'Kufri Badshah' was planted under four planting dates (22nd October 1st, 11th and 21st November) and four fertilizer combinations (recommended (150 N: 50 P: 100 K Kg ha^{-1}), 75%, 125% 150% of recommended). Tubers from each treatment were stored up to 60 days under ambient conditions and physiological losses, rotting percentage and sugar content dynamics were investigated. Tubers obtained from the planting of 22nd October recorded the lowest physiological loss in weight (PLW) as well as minimum rotting losses (RL). Physiological loss in weight of stored tubers decreased while rotting of stored tubers increased with increase in fertilizer dose. Irrespective of the treatment, both the total sugars as well as PLW of tubers increased with increase in storage period. Rotting losses of tubers were also the highest from the 21st November planted crop. No treatment combination significantly affected sprouting of tubers. Potato tubers from October planted and supplied with recommended fertilizer can be best suited for storage under ambient conditions.

KEY WORDS: NPK, Physiological losses, Storage.

INTRODUCTION

Potato is the most important food crop and in the 1st decade of 21st century per capita annual global consumption was 33 kg (FAO, 2008). The growth of potato consumption has been further promoted by the emergence of snack and fast food trends (Verma, 1991). Food production wise it ranks 4th in the world and 3rd in India. Area under potato in India is 1.83 million hectares with production of 42.3 million tons (FAO, 2013). Its production depends upon the contribution of many factors, among them; planting time is the major one. In addition to it, judicious use of balanced dose of fertilizers like nitrogen, phosphorus and potassium for different planting times also plays an important role in the production of potato (Rai *et al*., 2002). Indo-Gangetic plains contribute 90 per cent of total potato production in India, where the crop is harvested from January to March before the onset of long hot summers. Market flooding with fresh potatoes results in sharp decline in prices which ultimately leads to financial losses to the farmers. Therefore, to avoid these market gluts temporarily, there is a need to keep potatoes under ordinary room/ambient conditions to regulate its supply in the market when the prices are more remunerative. This study was conducted with the objective to investigate the effects of planting time and fertilizer dose on the storability of potato tuber. The information from this study will help the farmers deciding appropriate planting time in combination with adequate fertilizer dose to enhance the storability of potato tubers under ambient conditions.

MATERIALS AND METHODS

The experiment was conducted at the Vegetable Research Farm and laboratory of the Department of Vegetable Crops, CCS Haryana Agricultural University, Hisar during cropping season 1 and 2. The experiment comprised of sixteen treatments (four dates of planting i.e. 22nd October (D_1), 1st(D_2), 11th(D_3) and 21st November (D_4) and four levels of fertilizer doses i.e. (RFD_0) recommended (150:50:100 Kg ha^{-1}), 75% (RFD_1), 125%(RFD_2), 150% (RFD_3) of recommended) using Kufri badshah cultivar. Planting of potato tubers was done at an interval of ten days during both the years. Seventy five per cent of nitrogen, whole of P_2O_5 and K_2O were applied as band placement on both sides of the tubers before furrows making and remaining twenty five per cent of nitrogen was applied at the time of earthing up after 30 days of plantings. Planting was done at 60 cm (between) x 20 cm (within) spacing in a randomized block design with three replications. All the recommended cultural practices were adopted during the course of experimentation. The haulm cutting was done after 100 days of planting. The treatments were harvested after ten days of haulm cutting to allow tuber curing in the field. The storage behavior of all the treatments was studied between the months March to May at room temperature during both the seasons of study. Tubers were kept for 3 days in a shady and airy place for curing before initiating storage studies. Five kilograms of B grade counted tubers of uniform size were kept in small hessian bags in three replications. Room temperature and relative humidity of both the years of experiment were recorded and given in Figure 1. The details of observations recorded during storage are mentioned as under:

Physiological Measurements

For estimation of Physiological loss in weight (PLW) 10 tubers per plot were randomly selected and marked as 1 to 10 during the period of storage. Successive weights of individual tubers were recorded at an interval of 15 days for

estimating the cumulative percent physiological weight reduction from March to May by using the formula:

$$PLW\ (\%) = \frac{Wi - Wj}{Wi} \times 100$$

Where, Wi=Total initial weight of tubers
Wj= Weight of healthy tubers left

Rotting percentage was recorded by counting the number of rotten tubers from total stored at 15 days interval. Per cent weight loss due to rotting was also calculated at an interval of 15 days by dividing weight of rotten tubers by initial weight of healthy tubers. Total weight loss was recorded by adding physiological weight loss and losses due to rotting at 15 days interval. Per cent sprouting was calculated from total counted tubers having one or more sprouts above 2 mm length at 15 days interval.

A separate sample from each treatment was kept under same storage conditions and sub-samples were taken at 15 days interval for estimation of total sugar. Total sugar content was estimated according to the method of Yemn and Wills (1954). 0.2 ml solution was taken, five ml of 0.2 per cent enthrone reagent was added and shaken. Boiled for 10 minutes and then cooled rapidly. The intensity of green color was measured at 625 nm.

Statistical Analysis

Data recorded on physiological loss in weight, rotting percentage, weight loss due to rotting, total weight loss, sprouting percentage and total sugars were subjected to analysis of variance (ANOVA, $p< 0.05$) suggested by Panse and Sukhatme (1985) and means comparisons were done at $P <0.05$.

RESULT AND DISCUSSION

Physiological Loss in Weight (PLW)

Highest PLW of potato tubers was recorded from harvested produce of D_1 planting (2.13, 2.00% during season 1 and season 2, respectively) at 15 days after storage (DAS) followed by D_3, D_2 and D_1 plantings during both the years and all the treatments differed significantly from each other (Table 3). Similar trend in PLW was noticed when observations were recorded at 30, 45 and 60 days after storage. At 60 DAS, PLW of potato tubers was 7.28, 7.77, 8.60 and 9.23 per cent during season 1 and 6.79, 7.44, 7.90 and 8.30 per cent during season 2 from the produce of plantings of D_1, D_2, D_3 and D_4, respectively. Minimum PLW in D_1 planting was due to relatively low temperature during early phase of storage. All the treatments differed significantly from each other. It was interesting to note that the tubers obtained from the treatment supplied with highest dose of fertilizers (RFD_3) revealed lowest physiological weight loss (1.60%) on observation recorded on 15^{th} day followed by RFD_2 (1.65%), RFD_0 (1.74%) and RFD_1 (1.81%). This trend was noticed throughout the storage period and all the four treatments ranging from RFD_1 to RFD_3 differed statistically from one another up to 45 days of storage in terms of physiological losses. Further, data revealed an increase in PLW from 8.09 per cent to 8.36 per cent (season 1) and from 7.43 to 7.84 per cent (season 2) in the stored tubers obtained from the treatments supplied with lowest dose of fertilizers (RFD_0) to highest dose of fertilizers (RFD_3) in reverse order. Minimum PLW in D_1 planting was due to relatively low temperature during early phase of storage. Significantly lower physiological loss in weight was recorded in the tubers where higher rate of fertilizers was applied in the field. That may be due to increase in tuber dry matter content, with increase in fertilizer dose. Reduction in weight loss of tubers with application of higher dose of potassium has been reported earlier also (Singh *et al.*, 1996).

Table 1. Soil properties of experimental site

Component	Units	Season	
		S1	S1
Soil texture		Sandy loam	Sandy loam
pH		8.8	8.5
EC	$ds \cdot m^{-1}$	0.95	0.7
Organic carbon	%	0.6	0.56
Available N	$kg \cdot ha^{-1}$	149.5	138
Available P	$kg \cdot ha^{-1}$	22	24
Available K	$kg \cdot ha^{-1}$	384	378

Rotting Percentage

Increasing trend in rotting percentage of tubers was observed with delayed planting (Table 3). There was no rotting of tubers up to 30th day after storage and in season 2, rotting of tubers was observed only in D_4 planting (17.51%) at 60th day of storage. At 45 days after storage rotting of tubers was observed in season 1 and highest rotting percentage was observed in D_4 planting treatment (22.00%) followed by D_3 (12.16%) and D_2 (1.50%) plantings, moreover /also the difference between these dates was highly significant. However, there was no rotting of tubers stored from the treatment of D_1 planting. At 60th day of storage highest rotting percentage in season 1 was observed in the treatment of D4 planting (40.33%) followed by D3 (27.16%) D2 (10.00) and D_1 (2.66%) and all these four treatments differed significantly among themselves. Difference in rotting of tubers over the years was due to difference in storage temperature as it was higher (20.8-41.0 °C) during season 1 as compared to season 2 (16.6-38.4 °C). Lowest rotting percentage of tubers was noted at lowest fertilizer dose i.e. 75 per cent of RFD at 45 and 60th days of storage and this treatment was statistically differed with remaining three fertilizer treatments.

Table 2. Average monthly maximum and minimum temperature, relative humidity (RH) and rainfall (mm) at Hisar, Haryana, India during both the seasons

	Season 1				Season 2			
	Temperature (°C)		RH (%)	Rain fall (mm)	Temperature (°C)		RH (%)	Rain fall (mm)
Month	Max.	Min.			Max.	Min.		
October	32.4	13.9	61.2	0.0	30.8	15.5	64.3	7.3
November	26.3	7.7	59.0	0.0	28.6	9.7	64.3	0.0
December	19.8	7.7	80.8	2.2	22.4	5.8	71.1	0.5
January	17.2	5.8	83.6	3.4	17.9	3.8	72.5	4.4
Feburary	25.2	7.3	68.3	0.0	21.3	8.6	77.4	14.6
March	32.7	12.5	59.6	0.0	28.3	13.3	71.0	13.8
April	37.3	19.4	44.5	8.6	35.2	16.3	43.4	5.1
May	40.5	24.8	42.7	8.2	40.2	21.6	35.3	0.0

Variation in rotting (both by number and weight) was significantly affected by planting dates and fertilizer doses. There was no rotting during first 30 days of storage irrespective of treatment. In the season 1 minimum rotting was observed in the tubers obtained from D_1 planting and maximum in the tubers obtained from D_4 planting at 45 and 60 days of storage. The possible reason for this may be the lower temperature when tubers from D_1 planting were stored and higher when tubers from D4 planting were stored. During season 2 there was no rotting of tubers until the experiment was terminated at 60 days after storage in the tubers obtained from the treatment of D_1, D_2, D_3 plantings. Difference in rotting of tubers over the years was due to difference in storage temperature (Figure 1.) as it was higher (20.8-41.0°C) during 2004 (Fig. 1a) as compared to (16.6-38.4°C) in 2005 (Fig. 1b). Minimum rotting percentage was recorded in the tubers obtained from the treatment of lowest fertilizer dose applied (RFD_1) and maximum in the tubers obtained from the treatment of highest fertilizer dose applied. Similar reports were also given by Chaurasia and Singh (1992), Mehta and Singh (2002) and Patel *et al.* (2002).

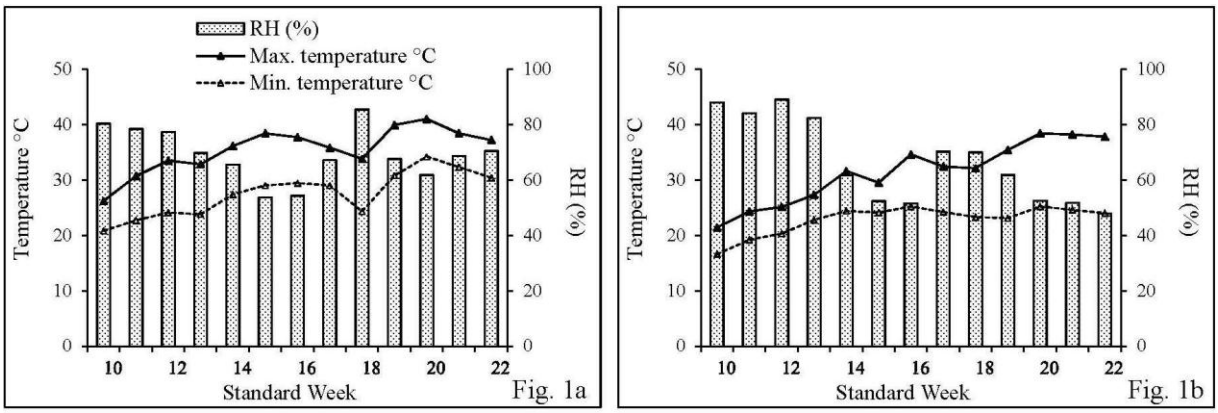

Figure 1. Weekly temperature and relative humidity patterns of storage conditions during March to May months during season 1 (Figure 1a) and season 2 (Figure 1b)

Table 3. Effect of planting dates and fertilizer doses on physiological weight (PLW) (w/w; %) and rotting of tubers (w/w; %) days after storage (DAS) under room temperature

Treatment	Physiological weight loss (%; DAS)								Rotting of tubers (%; DAS)			
	15		30		45		60		45		60	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Planting date												
D_1	1.29	1.07	2.28	2.1	5.08	4.85	7.28	6.79	0	0	2.66	0
D_2	1.58	1.54	2.35	2.25	5.34	5.17	7.77	7.44	1.5	0	10	0
D_3	1.81	1.83	3.17	3.06	5.75	5.32	8.6	7.9	12.16	0	27.16	0
D_4	2.13	2	3.65	3.31	6.21	5.67	9.23	8.3	22	0	40.33	17.51
CD at 5%	0.02	0.07	0.04	0.07	0.06	0.06	0.04	0.12	1.68		2.06	--
Fertilizer dose N:P:K (kg· ha^{-1})												
RFD_0	1.81	1.73	2.99	2.84	5.71	5.43	8.36	7.84	9.11	0	16.5	14.7
RFD_1	1.74	1.64	2.9	2.73	5.64	5.31	8.26	7.71	11.11	0	18.66	16.37
RFD_2	1.65	1.56	2.82	2.62	5.56	5.18	8.17	7.52	13.11	0	21.83	18.65
RFD_3	1.6	1.5	2.74	2.54	5.47	5.08	8.09	7.43	14.22	0	23.16	20.35
CD at 5%	0.02	0.07	0.04	0.07	0.06	0.06	0.04	0.12	1.94		2.06	1.25

Abbreviations: 22nd October (D1), 1st (D2), 11th (D3) and 21st November (D4); Recommended Fertilizer dose (150:50:100 Kg ha-1) (RFD); 100 % RFD (RFD0), 75% RFD (RFD1), 125% RFD (RFD2), 150% RFD (RFD3).
S1=season 1; S2=Season 2

Table 4. Effect of planting dates and fertilizer doses on per cent physiological weight loss (cumulative) and total weight loss (PLW+Rottage) and sprouting during storage under room temperature

Treatment	Per cent loss in weight				Total weight loss (PLW+Rottage)				Sprouted tubers (%)			
	45		60		45		60		45		60	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Planting date												
D_1	0	0	2.91	0	5.08	4.85	10.17	6.79	0	0	0	1.21
D_2	1.56	0	9.64	0	6.9	5.17	17.42	7.44	0	0	1.66	2.3
D_3	12.17	0	26.99	0	17.93	5.32	36.09	7.98	0.83	0	2.16	2.13
D_4	21.63	0	40.28	18.24	27.9	5.67	49.51	26.54	1.16	0	1.91	0
CD at 5%	1.42		1.91	ns	1.2	0.06	1.79	0.66	ns	ns	ns	ns
Fertilizer dose N:P:K (kg·ha^{-1})												
RFD_0	1.81	1.73	2.99	2.84	5.71	5.43	8.36	7.84	9.11	0	16.5	14.7
RFD_1	1.74	1.64	2.9	2.73	5.64	5.31	8.26	7.71	11.11	0	18.66	16.37
RFD_2	1.65	1.56	2.82	2.62	5.56	5.18	8.17	7.52	13.11	0	21.83	18.65
RFD_3	1.6	1.5	2.74	2.54	5.47	5.08	8.09	7.43	14.22	0	23.16	20.35
CD at 5%	0.02	0.07	0.04	0.07	0.06	0.06	0.04	0.12	1.94	ns	2.06	1.25

Abbreviations: 22nd October (D1), 1st (D2), 11th (D3) and 21st November (D4);
Recommended Fertilizer dose (150:50:100 Kg ha-1) (RFD); 100 % RFD (RFD0), 75% RFD (RFD1), 125% RFD (RFD2), 150% RFD (RFD3).
S1=season 1; S2=Season2
ns = statistically no significant differences at 5% level of significance.

Weight Loss Due To Rotting

Increasing trend in weight loss due to rotting was observed with delayed planting (Table 4.). There was no rotting up to 60th days of storage in season 2 except in the D_4 treatment of planting (18.24%). At 45 days after storage rotting losses were observed only in season 1 and highest weight loss due to rotting was observed in D_4 planting (21.63%) followed by D_3 (12.17%) and D_2 (1.56%) and difference between these dates was highly significant. However, there was no rotting of tubers stored from the treatment of D_1 planting. At 60th day of storage maximum weight loss due to rotting in season 1 was observed in the treatment of D_4 planting (40.28%) followed by the treatments in D_3 (26.99%), D_2 (9.64%)

and D_1 planting (2.91%) and all these four treatments differed significantly from one another. Minimum rotting losses was observed at lowest fertilizer dose i.e. RFD_1 at 45 and 60th days of storage and all four fertilizer treatments significantly differed among themselves.

Table 5. Effect of planting dates and fertilizer doses on total sugars of tubers during storage

Treatment	Total soluble solids (TSS)									
	0		15		30		45		60	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Planting date										
D_1	8.06	8.25	8.56	9.08	9.45	9.63	9.72	10.23	10	10.61
D_2	8.1	8.3	8.54	9.16	9.49	9.61	9.76	10.26	10.04	10.65
D_3	8.15	8.49	8.6	9.2	9.55	9.63	9.79	10.3	10.1	10.67
D_4	8.19	8.5	8.64	9.27	9.62	9.69	9.78	10.34	10.18	10.72
CD at 5%	0.06	0.17	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Fertilizer dose N:P:K ($kg \cdot ha^{-1}$)										
RFD_0	8.1	8.33	8.51	9.11	9.45	9.61	9.73	10.25	10.05	10.65
RFD_1	8.12	8.35	8.55	9.15	9.54	9.62	9.75	10.28	10.07	10.65
RFD_2	8.13	8.4	8.61	9.21	9.55	9.65	9.7	10.28	10.09	10.67
RFD_3	8.15	8.45	8.65	9.23	9.58	9.68	9.87	10.33	10.1	10.7
CD at 5%	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Abbreviations: 22nd October (D1), 1st (D2), 11th (D3) and 21st November (D4); Recommended Fertilizer dose (150:50:100 Kg ha-1) (RFD); 100 % RFD (RFD0), 75% RFD (RFD1), 125% RFD (RFD2), 150% RFD (RFD3).
S1=season 1; S2=Season2
ns = statistically no significant differences at 5% level of significance.

Total Weight Loss

Up to 30th day of storage, the loss in weight was only due to physiological loss in weight (Table 4.). In season 1, highest total weight loss was observed in D_4 planting (27.90, 49.51%) followed by D_3 (17.90, 36.09%), D_2 (6.90, 17.42%) and D_1 (5.08, 10.17) at 45th and 60th days of storage, respectively and all the planting treatments were significantly differed with one another. In season 2 total losses in weight was very less in comparison to season 1, and highest total loss in weight was noted in D_4 planting (26.54%) at 60th days of storage. Minimum total loss in weight was observed at lowest fertilizer dose (RFD_1) followed by RFD_0, RFD_2 and RFD_3. Since physiological loss in weight and rotting was lowest in the tubers of D_1 planting, therefore, total weight loss (physiological weight loss + rotting losses) was also lowest in D_1 planting closely followed by D_2 planted crop and highest in D_4 planting during both the seasons). Total weight loss was much higher in season 1 because of higher temperature in comparison to season 2. Minimum total weight loss during storage was recorded in the tubers obtained from the treatment of lowest fertilizer dose (RFD_1) and maximum RFD_3. It is due to more rotting losses caused by higher fertilizer doses applied in the field.

Sprouting Percentage

Effect of planting dates and fertilizer doses on sprouting of tubers was non-significant during storage period up to 60th days of storage (Table 4). There was no sprouting of tubers up to 30th days of storage in season 1 and 45th days of storage in season 2. Maximum sprouting of tubers was observed in D_3 planting (season 1) and D_2 planting (season 2) at 60th days of storage. Per cent sprouting of tubers was not influenced by any of the treatments during any of the two years of investigation.

Total Sugars

There was an increasing trend for total sugars with an increase of storage period irrespective of different experimental treatments (Table 3.). At the time of storage highest level of total sugars was observed in D_4 planting (8.19, 8.50 mg/g during season 1 and season 2, respectively) followed by D_3 (8.15, 8.49), D2 (8.10, 8.30) and D_1 (8.06, 8.25) plantings. D_4 planting par with D_3, but statistically differed with D_2 and D_1 plantings. The effect of planting dates and fertilizer doses on total sugars at 15, 30, 45 and 60th days of storage was non-significant. However, at the time of start of storage

experiment, sugar content of tubers was highest from the produce of D_4 planted crop and lowest from the D_1 planted crop. In general, sugar content of stored tubers increased during storage under ambient condition, irrespective of different treatments.

Conclusion

Physiological loss in weight as well as rotting percentage during storage under ambient condition was lowest in the tubers obtained from 22nd October planted crop. Similarly, PLW of tubers harvested from the treatment supplied with higher fertilizer doses also decreased. Therefore, it can be concluded that early planting and higher fertilizer may enhance the storability attribute of potato under Hisar conditions.

Acknowledgements

This work was supported by Department of Vegetable Science, CCSHAU, Hisar, India. We are thankful Department of Vegetable Crops, PAU, Ludhiana and Director of Extension Education, PAU, Ludhiana, Dr. R.K. Sood for their assistance in the completion of this research work.

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