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Original Paper

The influence of planting dates and field management on bulb quality and post-harvest losses of onion

Hamid Salari[1]*, R.S. Antil[2], Yashpal Singh Saharawat[3]

[1]*Amity University Uttar Pradesh, Amity Institute of Horticulture Studies and Research, Noida, India*
[2]*Amity University Uttar Pradesh, Amity Food and Agriculture Foundation, Noida, India*
[3]*Indian Agriculture Research Institute, Department of Soil Science, New Delhi, India*

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The present investigation was carried out to study the influence of planting date and field management practices on bulb quality and post-harvest losses of onions in storage at Agriculture Research Farm of Kabul University. Different traits including fresh bulb weight, total soluble solids, firmness, rooting, sprouting, spoilage and marketable bulbs were studied in these trials. The data were statistically analysed with R software. The planting dates had significant effect on fresh bulb weight, sprouting, spoilage and marketable bulbs of onions. After 120 days of storage the greatest fresh bulb weight (111.64 g), marketable bulbs (77.52%) and the lowest sprouting (10.56%) and spoilage (11.92%) were recorded for the first planting date (10th May). Similarly, the lowest loss in total soluble solids was also observed under the first planting date. Field management practices did not have significant effect on bulb quality and post-harvest losses of onions. While delayed planting can significantly reduce onion bulb quality and increase sprouting and spoilage, early planting dates were more appropriate to reduce post-harvest losses.

Keywords: *Allium cepa* L., fresh bulb weight. total soluble solids (TSS), sprouting, spoilage

1 Introduction

Onion (*Allium cepa* L.) belonging to the Alliaceae family is one of the leading vegetables grown throughout the world. The wild varieties of onion are originated from Central Asia comprising Iran, Afghanistan, Pakistan, Tajikistan, Uzbekistan, north-west India and Baluchistan (Mehta, 2017; Salari et al., 2020). Due to adaptation to the specific climatic conditions of the region, the cultivation of local varieties is common among farmers in Afghanistan. Safid e Paisaye is a local onion variety grown in central Afghanistan. The bulbs of this variety are white in colour and flat round in shape. The variety is famous for long storability of bulbs (Salari et al., 2020).

Sprouting, rooting and spoilage are the major storage problems of onion bulbs in Afghanistan. The bulbs are generally stored in natural ventilated storage facilities without proper control of temperature and relative humidity. The onions are stored for 3-5 months during fall and winter, and it starts sprouting, rooting and spoilage when temperature rises during early spring. Yasin & Bufler (2007) reported that appearance of sprouting in onion bulbs shows the end of storage life and the bulbs losses its market acceptance.

Pre-harvest factors, harvesting stage, transportation and storage environment influence the produce quality (Madakadze & Kwaramba, 2004). Studies reveal that, bulb quality has influence on storage potential of onions. González (1997) reported highest storage potential and higher yield for large sized bulbs obtained from early planted onions. He found that delayed onion planting caused thick necked bulbs with small size, lower yield and reduced storability. Ward (1979) reported that, date of sprouting initiation is not influenced by bulb size, but larger bulbs sprout faster once it is started. He further stated that, delayed harvesting increases the sprouting of bulbs in storage.

The bulb weight loss, spoilage and sprouting increases with increase in storage duration (Abubakar et al., 2019). Bulb weight loss increases with increase in bulb size

***Corresponding Author:** Hamid Salari, Kabul University, Agriculture Faculty, Horticulture Department, Jamal Mina, Kabul city, Kabul, Afghanistan, e-mail: h.salari@yahoo.com

and the highest weight loss is recorded for onion bulbs having diameter of 7 cm or higher (Abubakar et al., 2019). Small sized bulbs having a diameter of less than 5 cm recorded the highest sprouting (Abubakar & Ahmed, 2019). Sohany et al. (2016) found that increase in storage period decreases the total soluble solids (TSS) of onion bulbs and increases the weight loss.

The transplanting dates of onion seedlings vary widely among regions which confirms the influence of environmental conditions on onion growth, yield, and quality of bulbs (Ali et al., 2016; Bharti & Ram, 2014; Misra et al., 2014).

This investigation was conducted to study the effect of different planting dates and field management practice on bulb quality and post-harvest losses of onions in storage.

2 Material and methods

The study was conducted at the Agriculture Research Farm of Kabul University during 2018/2019 and 2019/2020. The research field falls under dry temperate climatic zone of Afghanistan (Salari et al., 2020).

The trials were laid out in Split-Split Plot Randomized Complete Block Design (RCBD). The tillage depths at two level (25 cm and 10 cm) were placed in main plots. The land preparation methods at three level (flatbed, raised bed – single row, raised bed – double row) were allocated in sub plots. The planting dates at three level (10th May, 1st June and 20th June) were randomly applied in sub-sub plots. Each treatment was replicated three times.

Based on experiment details, the plots were ploughed to the depths of 10 cm and 25 cm. The plot beds were prepared in form of 1) flat bed, 2) raised beds with the height and width of 10 and 20 cm respectively – a single row of onion plants was cultivated on top of raised bed and 3) raised beds with the height and width of 10 and 40 cm respectively – two rows of onion plants were cultivated on top of it. The seeds were raised in nursery for 8 weeks prior to transplanting to the field. For the transplanting dates 10 May, 1 June, and 20 June, the seeds were sown in nursery on 10 March, 1 April, and 20 April, respectively.

The recommended dosage of inorganic fertilizer (nitrogen at 90 kg ha^{-1}, phosphorus at 60 kg ha^{-1} and potassium at 45 kg ha^{-1}) and farmyard manure at 15 t ha^{-1} were applied to all the plots. The plots were irrigated using common flood irrigation. Considering the climatic conditions, the frequency of irrigation was decided once in each 7–10 days. The plants were grown with rows spaced 0.2 m apart and an in-row plant distance of 0.12–0.15 m. The weeds were controlled manually by hand weeding. To control fungal diseases especially powdery mildew, the leaves were sprayed with 0.2% Mancozeb fungicide solution especially during the rainy season.

When 50% leaves dried, the bulbs were harvested and cured for one month under ventilated conditions. The cured bulbs were stored in mesh bags under natural ventilated storage conditions for a period of 4 months. During the storage period, the mean temperature of storage ranged from -0.09 °C to 4.88 °C and the relative humidity ranged from 56.38 to 95.51 percent. The monthly average temperature and relative humidity of the storage facility are presented in table 1.

The data of bulb quality parameters was recorded at initial, 60 days of storage and 120 days of storage. The fresh bulb weight in grams was recorded using digital weighing balance. TSS (Brix) was recorded with hand refractometer (0–32 °B) and firmness (kg cm^{-2}) was recorded with penetrometer (13 kg). The probe of penetrometer was one cm in diameter and the data was presented in kilograms per square centimetre. The number of bulbs with visual signs of sprouting, rooting and spoilage were recorded and were presented in percentage. The number of healthy bulbs were presented as percent marketable bulbs.

The recorded data were statistically analysed with R software. ANOVA was calculated according to split-split

Table 1 Average temperature and relative humidity of storage facility during onion storage period (pooled mean of two seasons)

Month	Maximum temperature (°C)	Minimum temperature (°C)	Mean temperature (°C)	Relative humidity (%)
October	8.49	1.27	4.88	56.38
November	5.10	-0.43	2.33	72.68
December	3.58	-1.52	1.03	63.52
January	2.15	-2.32	-0.09	73.61
February	2.00	-2.46	-0.23	95.51
March	5.34	-0.36	2.49	86.97
Average	4.44	-0.97	1.73	74.78

plot RCBD and main effects were separated using Least Significant Difference (LSD) at $P = 0.05$. The results are explained for significant interactions.

3 Results and discussion

3.1 Fresh bulb weight

Planting date had highly significant effect on fresh bulb weight at all three stages of storage in both season 2018/2019 and 2019/2020 and mean of two seasons (Table 2). Based on mean values, the highest fresh bulb weight (126.67 g) at initial stage was recorded for the first planting date (10 May) which gradually decreased to 111.64 g after 120 days of storage. The lowest fresh bulb weight (76.80 g) at initial stage was recorded for third planting date (20 June) which gradually decreased to 69.95 g after 120 days of storage.

Optimum weather conditions during bulb enlargement stage especially higher temperature and longer day length might be the possible reasons for larger bulbs under early planting dates. The authors (Abdulsalam & Hamaiel, 2004; Bosekeng & Coetzer, 2013; Caruso et al., 2014; Salari et al., 2020; Singh & Singh, 2000)16 February, 3 March, 18 March also reported that early planted onion produces larger bulbs. Weight loss during storage is a natural phenomenon in horticultural products especially vegetables with high water contents. The weight loss is due to physiological activities especially transpiration which causes water loss and respiration which causes degradation of sugars. The authors (Abubakar et al., 2019; Abubakar & Ahmed, 2019; Jolayemi et al., 2018; Sohany et al., 2016) also reported that, onion lost its weight during storage.

3.2 Total doluble dolids (TSS)

The effect of planting date was significant on TSS at 120 days of storage during season 2019/2020 (Table 3). The highest TSS (8.94 Brix) was recorded for the first planting date (10 May) and the lowest (8.37 Brix) was recorded for second planting date (1st June).

The TSS was significantly influence by the interaction of tillage depth, land preparation and planting date at 120 days after storage during season 2019/2020 (Table 3). The highest TSS (9.70 Brix) was observed under the combination of shallow tillage, double row raised beds and first planting date, and the lowest (7.77 Brix) was observed under the combination of deep tillage, double row raised bed and first planting date (Figure 1).

The TSS has decreased during storage period which is due to physiological activities especially respiration taking place in fresh onion bulbs. The highest TSS reduction was observed in bulbs produced in third planting date. This might be due to early maturity of bulb, which means that onion grown in later stage has not spent enough period in the field to reach its proper physiological maturity. The results are in line with the findings of (Prasad et al., 2017; Sohany et al., 2016).

3.3 Firmness

Bulb firmness was significantly influenced by the interaction of tillage depth, land preparation and planting date at initial stage during season 2019/2020 (Table 4). The highest firmness (12.03 kg cm^{-2}) was observed under the combination of shallow tillage, flat bed and first planting date, and the lowest (8.77 kg cm^{-2}) was observed under the combination of deep tillage, flat bed and second planting date (Figure 1).

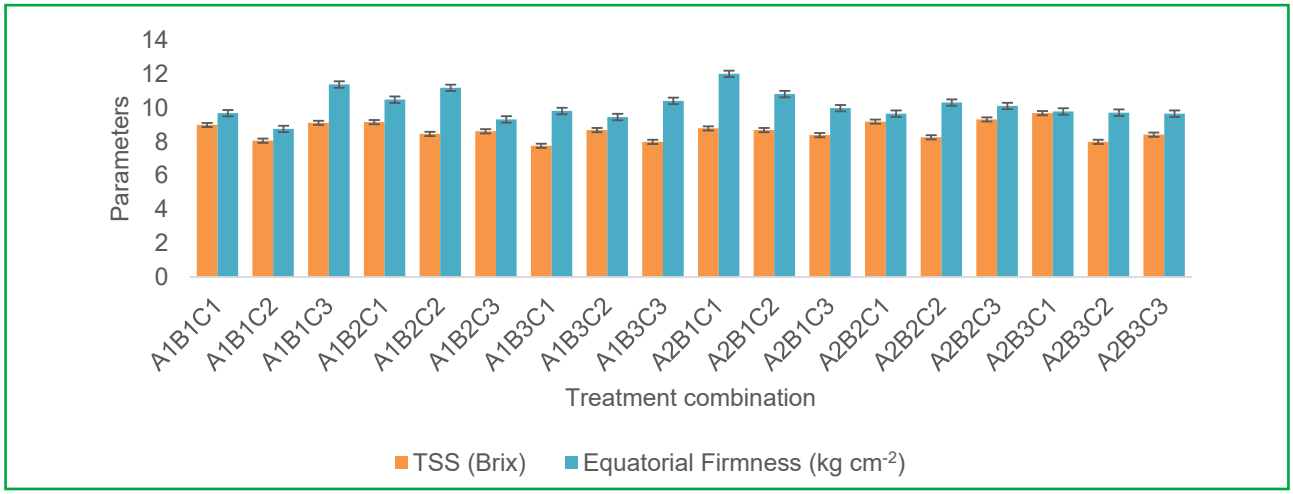

Figure 1 The TSS (at 120 days of storage) and firmness (at initial stage of storage) of Safid E Paisaye onion as affected by significant interaction among tillage depth (A), land preparation (B) and planting date (C) during season 2019/2020

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Table 2 Fresh bulb weight (g) of Safid E Paisaye onion as influenced by tillage depth, land preparation method, and planting date

Treatment	Storage period								
	initial			60 (days)			120 (days)		
	season 2018/2019	season 2019/2020	mean	season 2018/2019	season 2019/2020	mean	season 2018/2019	season 2019/2020	mean
Tillage depth (A)									
Deep tillage (25 cm)	92.81 ±5.3	119 ±7.3	105.91 ±5.9	86.48 ±6.7	111.7 ±6.5	99.09 ±5.2	80.81 ±6.3	108.96 ±6.4	94.89 ±5.1
Shallow tillage (10 cm)	87.11 ±6.9	109.11 ±7.2	98.11 ±5.6	80.96 ±5.0	104.37 ±6.8	92.67 ±5.4	75.25 ±4.9	100.52 ±6.7	87.89 ±5.2
F-test	NS	NS	NS	NS	NS	NS	NS	NS	NS
Land Preparation (B):									
Flat bed	98.38 ±7.4	109.39 ±7.2	103.89 ±6.0	92.22 ±7.1	105.94 ±6.9	99.08 ±5.7	86.66 ±6.5	103.22 ±6.7	94.94 ±5.5
Raised bed – single row	83.11 ±6.4	109.06 ±8.1	96.09 ±6.8	76.61 ±6.1	100.28 ±6.0	88.45 ±5.3	72.44 ±6.0	95.89 ±6.1	84.17 ±5.3
Raised bed – double row	88.38 ±8.5	123.72 ±10.9	106.05 ±8.3	82.33 ±8.3	117.89 ±10.6	100.11 ±8.0	75.00 ±7.9	115.11 ±10.4	95.06 ±7.7
F-test	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting date (C)									
10th May	121.0 ±6.2 a	132.3 ±9.0 a	126.7 ±5.8 a	113.7 ±6.2 a	121.9 ±8.1 a	117.8 ±5.2 a	105.9 ±6.4 a	117.4 ±8.6 a	111.6 ±5.7 a
1st June	88.5 ±4.9 b	116.6 ±8.6 a	102.6 ±5.8b	81.4 ±4.7b	112.8 ±8.2 a	97.1 ±5.6 b	74.9 ±4.7b	110.3 ±7.8 a	92.6 ±5.4 b
20th June	60.4 ±2.4 c	93.2 ±6.6b	76.8 ±3.7 c	56.1 ±2.2 c	89.4 ±6.3b	72.7 ±3.5 c	53.3 ±2.1 c	86.6 ±5.9 b	69.9 ±3.3 c
F-test	**	**	**	**	**	**	**	**	**
LSD	13.65	19.4	13.2	13.65	17.71	12	13.69	18.07	11.74
CV (%)	22.1	24.7	18.8	23.7	23.8	18.2	25.5	25.1	18.7
Interaction									
A × B	NS	NS	NS	NS	NS	NS	NS	NS	NS
A × C	NS	NS	NS	NS	NS	NS	NS	NS	NS
B × C	NS	NS	NS	NS	NS	NS	NS	NS	NS
A × B × C	NS	NS	NS	NS	NS	NS	NS	NS	NS

** and NS stands for highly significant and non-significant, respectively. Means within the same column for each factor followed by the same letter are not significantly different, according to LSD at 0.05 level. ±SEM

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Table 3 Total soluble solids (Brix) as influenced by tillage depth, land preparation method, and planting date of Safid E Paisaye onion

Treatment	Storage period								
	initial			60 (days)			120 (days)		
	season 2018/2019	season 2019/2020	mean	season 2018/2019	season 2019/2020	mean	season 2018/2019	season 2019/2020	mean
Tillage depth (A)									
Deep tillage (25 cm)	9.79 ±0.23	9.26 ±0.25	9.53 ±0.19	9.28 ±0.19	8.73 ±0.19	9.01 ±0.15	8.84 ±0.21	8.55 ±0.13	8.7 ±0.14
Shallow tillage (10 cm)	10.16 ±0.33	9.22 ±0.22	9.69 ±0.14	8.77 ±0.21	8.91 ±0.19	8.84 ±0.16	8.48 ±0.24	8.76 ±0.15	8.62 ±0.15
F-test	NS	NS	NS	NS	NS	NS	NS	NS	NS
Land preparation (B)									
Flat bed	9.91 ±0.37	9.26 ±0.33	9.59 ±0.23	9.01 ±0.33	8.82 ±0.2	8.92 ±0.21	8.56 ±0.35	8.68 ±0.12	8.62 ±0.18
Raised bed – single row	10.42 ±0.34	9.48 ±0.26	9.95 ±0.24	9.31 ±0.22	9.06 ±0.25	9.19 ±0.18	8.81 ±0.27	8.84 ±0.2	8.83 ±0.19
Raised bed – double row	9.59 ±0.31	8.99 ±0.28	9.29 ±0.13	8.75 ±0.18	8.59 ±0	8.67 ±0.17	8.61 ±0.2	8.43 ±0.19	8.52 ±0.16
F-test	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting date (C)									
10th May	10.00 ±0.25	9.39 ±0.25	9.70 ±0.17	8.84 ±0.18	9.05 ±0.21	8.95 ±0.14	8.5 ±0.26	8.94 ±0.18 a	8.72 ±0.17
1st June	9.55 ±0.45	9.24 ±0.33	9.40 ±0.23	9.08 ±0.32	8.63 ±0.27	8.86 ±0.25	8.83 ±0.33	8.37 ±0.15b	8.60 ±0.21
20th June	10.38 ±0.3	9.09 ±0.29	9.74 ±0.23	9.14 ±0.24	8.78 ±0.22	8.96 ±0.18	8.65 ±0.24	8.66 ±0.17 ab	8.66 ±0.16
F-test	NS	NS	NS	NS	NS	NS	NS	*	NS
LSD								0.45	
CV (%)								7.5	
Interaction									
A × B	NS	NS	NS	NS	NS	NS	NS	NS	NS
A × C	NS	NS	NS	NS	NS	NS	NS	NS	NS
B × C	NS	NS	NS	NS	NS	NS	NS	NS	NS
A × B × C	NS	NS	NS	NS	NS	NS	NS	*	NS

* and NS stands for significant and non-significant, respectively. Means within the same column for each factor followed by the same letter are not significantly different, according to LSD at 0.05 level. ±SEM

Table 4 Firmness (kg cm^2) of Safid E Paisaye onion as influenced by tillage depth, land preparation method, and planting date

Treatment	Storage period								
	initial			60 (days)			120 (days)		
	season 2018/2019	season 2019/2020	mean	season 2018/2019	season 2019/2020	mean	season 2018/2019	season 2019/2020	mean
Tillage depth (A)									
Deep tillage (25 cm)	10.05 ±0.25	10.07 ±0.24	10.06 ±0.17	11.3 ±0.26	11.01 ±0.21	11.16 ±0.22	10.11 ±0.27	9.15 ±0.23	9.63 ±0.18
Shallow tillage (10 cm)	10.85 ±0.22	10.24 ±0.23	10.55 ±0.17	10.84 ±0.3	10.94 ±0.19	10.89 ±0.22	9.8 ±0.23	9.66 ±0.28	9.73 ±0.19
F-test	NS	NS	NS	NS	NS	NS	NS	NS	NS
Land preparation (B)									
Flat bed	10.63 ±0.25	10.46 ±0.33	10.55 ±0.19	11.11 ±0.29	11.14 ±0.24	11.13 ±0.23	9.82 ±0.25	9.63 ±0.33	9.73 ±0.21
Raised bed – single row	10.39 ±0.23	10.19 ±0.29	10.29 ±0.22	10.81 ±0.33	10.91 ±0.26	10.86 ±0.26	9.98 ±0.27	9.38 ±0.36	9.68 ±0.23
Raised bed – double row	10.34 ±0.41	9.82 ±0.22	10.08 ±0.21	11.28 ±0.42	10.88 ±0.24	11.08 ±0.31	10.06 ±0.39	9.19 ±0.26	9.63 ±0.24
F-test	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting date (C)									
10th May	10.36 ±0.31	10.26 ±0.32	10.31 ±0.24	11.13 ±0.34	11.06 ±0.27	11.1 ±0.28	10 ±0.21	9.54 ±0.39	9.77 ±0.22
1st June	10.51 ±0.35	10.06 ±0.29	10.29 ±0.21	10.9 ±0.42	10.89 ±0.25	10.9 ±0.3	9.73 ±0.39	9.28 ±0.25	9.51 ±0.27
20th June	10.49 ±0.25	10.16 ±0.26	10.33 ±0.18	11.17 ±0.29	10.98 ±0.22	11.08 ±0.22	10.12 ±28.99	9.38 ±0.31	9.75 ±0.18
F-test	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
A × B	NS	NS	NS	NS	NS	NS	NS	NS	NS
A × C	NS	NS	NS	NS	NS	NS	NS	NS	NS
B × C	NS	NS	NS	NS	NS	NS	NS	NS	NS
A × B × C	NS	**	NS	NS	NS	NS	NS	NS	NS

** and NS stands for highly significant and non-significant, respectively. Means within the same column for each factor followed by the same letter are not significantly different, according to LSD at 0.05 level. ±SEM

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The larger bulbs produced in early planting date had higher firmness as compared to smaller bulbs produced in later planting dates. The proper maturity of early planted bulbs might be the reason for higher firmness. The results are in line with the findings of (Gagopale & Coetzer, 2015).

3.4 Rooting

No visual signs of bulb rooting were observed during the storage period of 120 days.

3.5 Sprouting and spoilage

No visual signs of bulb sprouting, and spoilage were observed during the first 60 days of storage period. The planting date had significant effect on sprouting of bulbs at 120 days of storage during season 2019/2020 and mean for two seasons (Table 5). Based on mean value, the highest bulb sprouting (14.77%) was observed in third planting date (20th June) and the lowest (10.56%) was observed in first planting date (10th May).

The planting date had significant effect on bulb spoilage at 120 days of storage (Table 5). The highest bulb spoilage (18.56%) was observed in third planting date (20th June) and the lowest (11.92%) was observed in first planting date (10th May).

The effect of interaction of tillage depth and land preparation method was found significant on sprouting of bulbs at 120 days of storage during season 2018/2019 and mean of two seasons (Table 5). According to the mean values of two seasons, the highest bulb sprouting (16.31%) was observed in combination of shallow tillage and double row raised beds and the lowest (7.91%) was observed in combination of deep tillage and double row raised bed (Figure 2). The effect of interaction of land preparation method and planting date was also found significant at 120 days of storage during season 2019/2020 (Table 5). The highest bulb sprouting (16.00%) was observed in combination of single row raised beds and third planting date (20th June) and the lowest (1.33%) was observed in combination of single row raised bed and second planting date (1st June) (Figure 3).

The onion produced in early planting dates has spent more period in the field and reached optimum maturity. This might be the possible reason for less sprouting and spoilage of onion produced in early planting dates. The authors (Abubakar et al., 2019; Abubakar & Ahmed, 2019; Ward, 1979) also reported that bulbs produced in early planting dates has less sprouting and spoilage as compared to those produced in later planting dates.

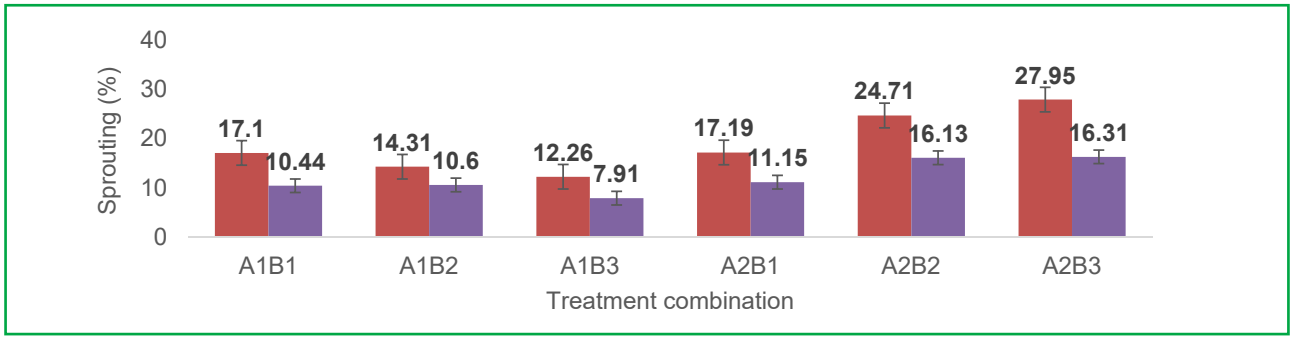

Figure 2 Sprouting of Safid E Paisaye onion as affected by significant interaction among tillage depth (A) and land preparation methods (B) at 120 days of storage during season 2018/2019 and mean of both seasons

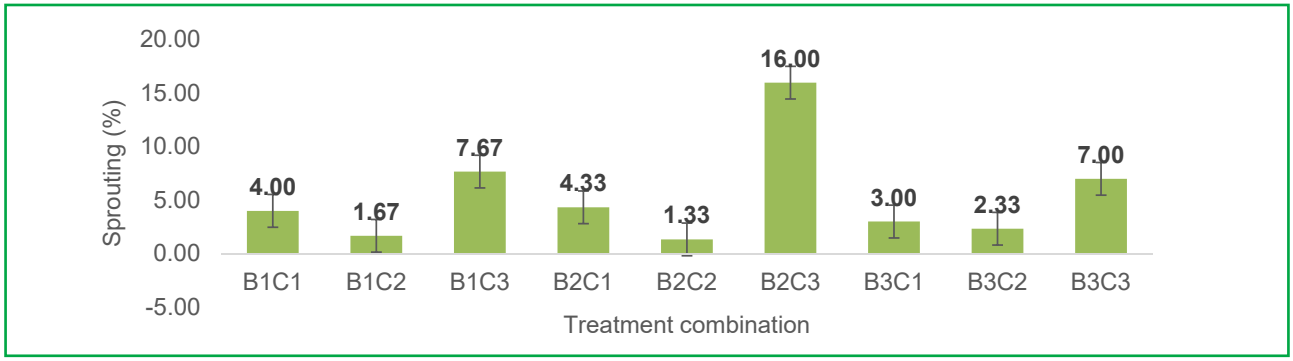

Figure 3 Sprouting percentage of Safid E Paisaye onion as affected by significant interaction among land preparation (B) and planting date (C) at 120 days of storage during season 2019/2020

Table 5 Sprouting and spoilage of bulbs as influenced by tillage depth, land preparation method, and planting date of Safid E Paisaye onion

Treatment	Storage period (120 days)					
	sprouting (%)			spoilage (%)		
	season 2018/2019	season 2019/2020	mean	season 2018/2019	season 2019/2020	mean
Tillage depth (A)						
Deep tillage (25 cm)	14.55 ±1.28	4.74 ±0.97	9.65 ±0.7	15 ±2.78	16.67 ±1.79	15.84 ±1.59
Shallow tillage (10 cm)	23.28 ±2.06	5.78 ±1.29	14.53 ±1.25	11.7 ±1.67	18 ±1.81	14.85 ±1.2
F-test	NS	NS	NS	NS	NS	NS
Land preparation (B)						
Flat bed	17.14 ±1.81	4.44 ±1.23	10.79 ±0.94	17.66 ±3.65	15.67 ±2.17	16.67 ±2.14
Raised bed – single row	19.51 ±2.16	7.22 ±1.83	13.37 ±1.43	12.99 ±2.57	17 ±2.38	15 ±1.73
Raised bed – double row	20.1 ±2.94	4.11 ±0.89	12.11 ±1.63	9.41 ±1.6	19.33 ±2.03	14.37 ±1.2
F-test	NS	NS	NS	NS	NS	NS
Planting date (C)						
10th May	17.34 ±1.8	3.78 ±0.77b	10.56 ±1.01b	12.61 ±3.48	11.22 ±1.61	11.92 ±1.83b
1st June	20.08 ±2.32	1.78 ±0.51b	10.93 ±1.13b	11.11 ±1.55	20 ±2.11	15.56 ±1.17 ab
20th June	19.32 ±2.82	10.22 ±1.69 a	14.77 ±1.68 a	16.33 ±3.03	20.78 ±2.14	18.56 ±1.78 a
F-test	NS	**	*	NS	NS	*
LSD		2.86	3.36			5.18
CV (%)		79	40.4			49
Interaction						
A × B	*	NS	*	NS	NS	NS
A × C	NS	NS	NS	NS	NS	NS
B × C	NS	*	NS	NS	NS	NS
A × B × C	NS	NS	NS	NS	NS	NS

*, ** and NS stands for significant, highly significant and non-significant, respectively. Means within the same column for each factor followed by the same letter are not significantly different, according to LSD at 0.05 level. ±SEM

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3.6 Marketable bulbs

No visual signs of bulb sprouting, rooting and spoilage were observed during the first 60 days of storage period, hence all stored bulbs were marketable.

The planting date had highly significant effect on percentage of marketable bulbs at 120 days of storage during season 2019/2020 and mean of two seasons (Table 6). Based on mean value, the highest percentage of marketable bulbs (77.52%) were observed in first planting date (10th May) and the lowest (66.67%) were observed in third planting date (20th June).

The effect of interaction of tillage depth and land preparation method was found significant on percentage of marketable bulbs at 120 days of storage during season 2018/2019 (Table 6). The highest percentage of marketable bulbs (76.44%) was observed in combination of deep tillage and double row raised beds and the lowest (61.32%) was observed in combination of deep tillage and flatbed (Figure 4). Similarly, the interaction of tillage depth, land preparation method and planting date had significant effect on percentage of marketable bulbs at 120 days of storage in mean values of season 2018/2019 and 2019/2020 (Table 6). The highest percentage of marketable bulbs (83.17%) was observed in combination of deep tillage, single row raised beds and first planting date (10th May) and the lowest (60.50%) was observed in combination of shallow tillage, double row raised bed and third planting date (20th June) (Figure 5).

The percentage of marketable bulbs is dependent on percentage of sprouted and spoiled onion bulbs. Since the number of sprouted and spoiled onion bulbs were recorded less for early planting dates then it is obvious that, the marketable bulbs would be higher. The results are in line with the findings of (Abubakar et al., 2019; Abubakar & Ahmed, 2019; Ward, 1979).

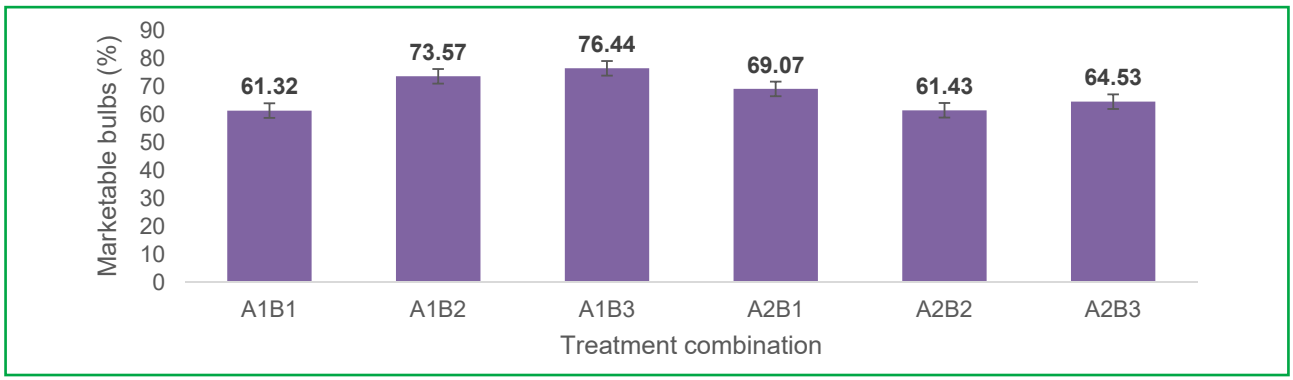

Figure 4 Marketable bulbs percentage of Safid E Paisaye onion as affected by significant interaction among tillage depth (A) and land preparation methods (B) at 120 days of storage during season 2018/2019

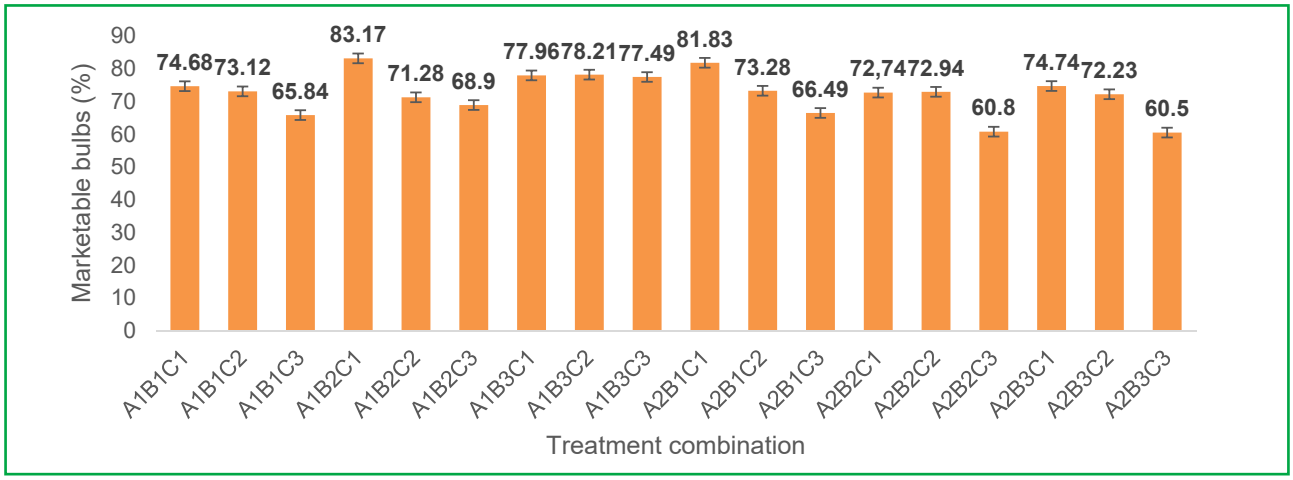

Figure 5 Marketable bulbs percentage of Safid E Paisaye onion as affected by significant interaction among tillage depth (A), land preparation method (B) and planting date (C) at 120 days of storage during mean of season 2018/2019 and 2019/2020

Table 6 Marketable bulbs (%) of onion variety Safid E Paisaye as influenced by tillage depth, land preparation method, and planting date

Treatment	Storage period (120 days)		
	season 2018/2019	season 2019/2020	mean
Tillage depth (A)			
Deep tillage (25 cm)	70.44 ±2.67	78.59 ±2	74.52 ±1.52
Shallow tillage (10 cm)	65 ±2.61	76.22 ±2.5	70.61 ±2.02
F-test	NS	NS	NS
Land preparation (B)			
Flat bed	65.19 ±3.62	79.89 ±2.73	72.54 ±2.22
Raised bed – single row	67.49 ±3.35	75.78 ±3.05	71.64 ±2.38
Raised bed – double row	70.48 ±2.85	76.56 ±2.53	73.52 ±2.15
F-test	NS	NS	NS
Planting date (C):			
10th May	70.04 ±3.8	85.00 ±1.73 a	77.52 ±1.98 a
1st June	68.79 ±2.77	78.22 ±2.28 a	73.51 ±1.43 a
20th June	64.33 ±3.17	69.00 ±2.82b	66.67 ±2.41b
F-test	NS	**	**
LSD		6.81	6.63
CV (%)		12.8	13.3
Interaction			
A × B	*	NS	NS
A × C	NS	NS	NS
B × C	NS	NS	NS
A × B × C	NS	NS	*

*, ** and NS stands for significant, highly significant, and non-significant, respectively. Means within the same column for each factor followed by the same letter are not significantly different, according to LSD at 0.05 level. ±SEM

4 Conclusions

Based on the findings of the study it is concluded that, date of planting plays crucial role in post-harvest losses of stored onions. Delay in planting date significantly increases sprouting and spoilage of onions in storage and reduces the percentage of marketable bulbs. This also increases physiological activities during storage and increase the loss of total soluble solids. The weight loss is dependent of bulb size and larger bulbs produced in early planting dates losses relatively higher weight as compared to small bulbs. To reduce the huge economic losses of onions due to sprouting and spoilage, the farmers are recommended to sow onions in nursery in early March and transplant them in early May. The tillage depth and land preparation methods do not have significant effect on quality of stored onions hence the farmers can follow the cheapest and easiest practice.

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