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RESEARCH ARTICLE

Effect of Integrated Nitrogen, Phosphorus, and Farmyard Manure on Post-Harvest Quality and Storability of Onion (*Allium Cepa* L.)

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ABSTRACT

A series of laboratory experiments were conducted during the 2011 and 2012 growing season under irrigation using 12 treatment combinations of NP and FYM at Melkassa Research Centre in the Central Rift Valley Region of Ethiopia. The objective of the experiment was to investigate the effect of integrated NP and FYM use on postharvest quality and shelf life of Bombay red onion bulbs. The experiment was laid out as a randomized complete block design with three replications per treatment in the store. Results of the study revealed that combined application of fertilizer at 51.75 kg N+ 69 kg P_2O_5 + 5 t FYM ha^{-1} resulted in minimum physiological weight loss of bulbs throughout the whole storage period. Sprouting was lowest in bulbs treated with 51.75 kg N+ 69 kg P_2O_5 + 5 t FYM ha^{-1} while it was highest at 138 kg N+ 184 P_2O_5kg+40 t FYM ha^{-1}. Application of 34.5 kg N+ 46 kg P_2O_5 + 10 t FYM ha^{-1} led to minimum bulb rotting. Total soluble solids(TSS) and percent dry matter recorded maximum with application of 51.75 kg N+ 69 kg P_2O_5 + 5 t FYM ha^{-1}. Pyruvate content of onion bulbs showed an increasing trend with increasing rates of fertilizer combinations, where treatment having 138 kg N+ 184 P_2O_5 kg+ 40 t FYM ha^{-1} recorded the highest. Highest marketability was recorded in bulbs treated with 86.25 kg N+115 kg P_2O_5+25 t FYM ha^{-1} fertilizer combinations. Marketability of bulbs dropped to about 85% after six weeks and 40% after 12 weeks of storage while the best treatment recorded 94% and 61.5% at respective storage periods. From results of the study, integrated application of 69 kg N+ 92 kg P_2O_5 + 20 t FYM ha^{-1} can be a good compromise for postharvest quality and shelf life of Bombay Red onion bulbs in the central Rift Valley region of Ethiopia.

Keywords: Farmyard manure, inorganic N P, onion, shelf life, quality

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INTRODUCTION

The onion (*Allium cepa* L.) is the most widely cultivated species of the genus *Allium* (Brewster, 2008). It accounts for around 10% of world's vegetable production, making it the second most important vegetable crop, following only tomato. In Ethiopia, onion is produced in different parts of the country for local consumption and export (Lemma and Shimeles, 2003), with the greater proportion obtained from the central Rift Valley region, which is mainly attributed to availability of irrigation potential and proximity to market (CSA, 2002; MOWR, 2007).

In subtropical regions, loss of quality in onion bulbs (*Allium cepa* L.) is of the great concern, where postharvest losses can be as high as 40% of total production due to sprouting, decay, rooting and weight loss. A comprehensive statistics for such losses is not found in Ethiopia; however, it has been estimated that in the state farms and in the peasant sector the post harvest losses may reach 25-35% for horticultural crops in general and 12% for onions in particular (Fekadu, 1991). Storage affords producers access to future market prices and income, reduces price fluctuations and market speculation, and improves competition and price stability (Jahanzab and Nabi, 2005).

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In Ethiopia, high storage losses compel onion producers to sell their produce immediately after harvest when the price is low (Lemma and Shimeles, 2003). Consequently, sometimes it becomes very difficult to cover even the production costs and, hence, creates discontent among growers in the region. Accordingly, Lema and Shimeles (2003) and Endeshaw et al. (2008) suggested that in central Rift Valley region (CRV) future research endeavors may need to establish the relationships between field management practices such as fertilizer management and storage life of onion bulb.

According to reports by Chung (1989), Brewster (1994) and Choudhury (2006), a web of complex interactions of factors contribute to quality of bulbs in post-harvest storage; these include mineral nutrition, cultivar, stage of bulb development and conditions during maturation, harvesting and curing. Several authors emphasized the need for optimizing fertilizers in improving postharvest quality and storability of onions (Chung, 1989; Komochi, 1990; Sorensen and Grevsen, 2001; Nabi et al*.,* 2010) reported that a combination of manure and synthetic fertilizer was superior to manure alone for crop productivity and food value in human nutrition. Lowest rotting, sprouting and total loss of onion bulb was noticed in the onion supplied with vermicompost at 3 t ha^{-1}. Similarly, the lowest storage losses of onion bulbs were noticed in the treatments received FYM at 25 t ha^{-1} along with NPK at 125: 25: 25 Kg ha^{-1} (Anon., 1996). Sankar *et al.* (2009) noticed improved storage life of yellow onion bulb with organic treatment combination of 3% panchagavya + 50% FYM + 50% poultry manure as compared to 100% recommended dose of NPK fertilizer.

Considering the above facts, however, in the CRV region of Ethiopia, there is no ample report on post-harvest quality and storability of onion with application of integrated farmyard manure and inorganic NP. The present study was, therefore, undertaken with the objective of evaluating response of onion to integrated NP and FYM application and identifying the optimum combination of the fertilizers that give better post harvest quality and storability of Bombay Red onion.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Melkassa Agricultural Research Centre, Ethiopian Institute of Agricultural Research, during 2011 and 2012. The center is situated in the central Rift Valley region of Ethiopia at latitude 8°24' N and longitude 39°21' E at an elevation of 1550 metres above sea level. The area has an average annual rainfall of 768 mm, which is erratic and uneven in distribution. The site has a mean maximum temperature of 28.5^{o}C and mean minimum temperature of 12.6°C (Tesfaye and Walker, 2004). Alluvial loam and clay loam are the dominant soil textures of the area **(**Samson et al*.,* 2006).

Treatments and experimental design

An onion variety named Bombay Red, which is the most widely cultivated variety in the region, was used for the study. Twelve treatment combinations of nitrogen, phosphorus and farmyard manure were used for the field experiment. The treatment combinations were T1=(0, 0, 0) *i.e.* control, T2=(0,0,20) *i.e*. only 20 t ha^{-1} FYM, T3=(69, 0, 20) *i.e.* recommended dose of inorganic N and 20 t ha^{-1} FYM, T4=(0, 92, 20) *i.e.* only recommended dose of inorganic P_2O_5 and 20 t ha^{-1} FYM, T5=(69,92,0) *i.e.* only recommended dose of inorganic N and P_2O_5(100%), T6=(17.25, 23,15) *i.e.* 25% inorganic N, P_2O_5 and 15 t ha^{-1} FYM, T7=(34.5,46,10) *i.e.* 50% recommended inorganic N, P_2O_5 and 10 t ha^{-1} FYM T8=(51.75, 69, 5) *i.e.* 75% recommended inorganic N, P_2O_5 and 5 t ha^{-1} FYM, T9=(69, 92, 20) *i.e.* recommended inorganic N, P_2O_5 and 20 t ha^{-1} FYM, T10=(86.25, 115,25) *i.e.* 125% recommended inorganic N, P_2O_5 and 25 t ha^{-1} FYM, T11=(103.5, 138, 30) *i.e.* 150% recommended inorganic N, P_2O_5 and 30 t ha^{-1} FYM and T12=(138, 184, 40) *i.e.* 200% recommended inorganic N, P_2O_5 and 40 t ha^{-1}FYM. The field experiment was laid out in a randomized complete block design replicated three times.

Marketable onion bulbs from each plot in the field were used for postharvest quality and shelf life studies at Melkassa Agricultural Research Center for two seasons, from May to 30 July 2011 and 2012. Before storage, onion bulbs were cured under shade for two weeks. Cured and topped bulbs of six kg per treatment in each replication, were stored in simple, naturally ventilated house constructed from mesh wire wall and corrugated iron sheet roofing. In the store treatments were arranged in randomized complete plot design with three replications. Daily storage air conditions were recorded using digital psychrometer units (Jenway-digital psychrometer 5105, U.K.). The mean monthly temperature of the store of the two years was 26.1°C, with an average daily relative humidity of 60.1%(Fig. 1).

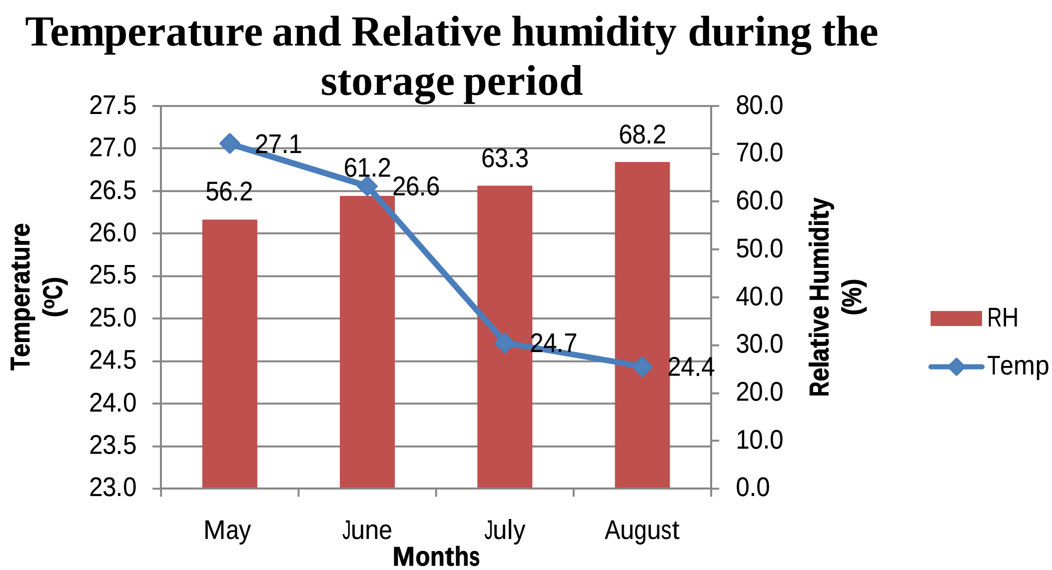

Figure 1. Mean monthly temperature and relative humidity of the storage room during 2011 and 2012

Data collection

Quality parameters were recorded from 5 randomly taken bulbs and the storage parameters were taken from remaining bulbs at two weeks interval throughout the three months storage period.

Dry matter (%): A homogenate was prepared from bulbs of each treatment. For determination of percent dry matter 25g of homogenate was taken and oven dried at a temperature of 70^{o}C until constant weight is reached. Then the weight was measured using digital balance.

Total soluble solids (%): Aliquot juice was extracted using a juice extractor and 50 ml of the slurry centrifuged for 15 minutes. The TSS was determined by hand refractometer (ATAGO TC-1E) with a range of 0 to 32^{0} Brix and resolutions of 0.2^{0} Brix by placing 1 to 2 drops of clear juice on the prism. The refractometer was standardized against distilled water (0% TSS).

Pungency (µ. mol/ml): The content of pyruvic acid developing in homogenized bulb tissue was used as measure of pungency following the procedure of Randle and Bussard (1993).

Weight loss of bulbs (%): was determined using the methods described by Waskar *et al.* (1999). The measurement was based on the difference in weight of bulbs at the beginning and at two weeks interval. The difference between the initial weight and successive weights was given as weight loss percentage.

Number of bulbs sprouted (%): Percentage of bulbs sprouted was cumulative, which was based on the number of bulbs sprouted in a two week interval storage period. The incidence of sprouting was ascertained by counting the number of bulbs sprouted. The sprouted bulbs were labeled after two weeks interval to avoid double counting. A bulb that sprouted and rotted at the same time was classified as sprouting.

Number of rotten bulbs (%): the measurement of percentage bulbs rotted was cumulative and based on the number of bulbs rotted. The incidence of rotting was determined by counting the number of bulbs rotted at two weeks interval. The rotted bulbs were labeled after two weeks interval count to avoid double counting.

Marketable bulbs (%)

Marketability of onion bulbs were evaluated at the end of three months storage period according to the scoring method used by Mohammed *et al.* (1999). Descriptive quality attributes were determined subjectively by observing the level of visible mould growth, sprouting, decay, shriveling of bulbs and color as visual parameters and over all acceptability of the product were recorded by the panelists. The number of marketable bulbs was used as measure to calculate the percentage marketable bulb. The marketable bulb was calculated by using the following formula.

$$\textbf{Marketable bulb (\%)} = \frac{\text{Number of marketable onion bulbs}}{\text{Initial number of onion bulbs stored}} \times 100$$

Data analysis

The collected data were subjected to analysis of variance using SAS (Statistical Analysis System, version 9.1, Copyright 2003, SAS institute Inc.USA). Homogeneity of variance test was done using Bartlett's test of SAS; as there was no significant difference, combined analysis of the two years data was used. Treatment mean differences were tested using Fisher's (LSD).

RESULTS

Percent Weight Loss

Pre-harvest fertilizer application significantly *($P \leq 0.001$)* affected physiological weight loss of onion bulbs during the whole storage period except at eighth week of storage (Table 1). Irrespective of treatments, physiological weight loss of onion bulbs increased from 3.39% at 2 weeks of storage to 21.47% at 12 weeks of storage period (Table 1). Minimum physiological weight loss (%) was noticed at the control treatment throughout the whole storage period. On the other hand, the highest physiological weight loss was observed at the highest dose of fertilizer application (Table 1).

Table 1. Effect of NP and FYM application on physiological weight loss (%) of onion bulbs under ambient storage condition

Percent weight loss						
Storage periods (weeks)						
Treatment*	2	4	6	8	10	12
0,0,0	3.39d	5.99d	7.98c	11.81	16.34d	19.53d
0,0,20	4.35b	7.08a	9.14ab	13.16	18.55ab	20.87abc
0, 92, 20	4.36b	7.01a	8.87b	12.43	18.02ab	20.89ab
69, 0, 20	4.16bc	6.69ab	9.00ab	12.38	18.61ab	20.85ab
69,92,0	4.19bc	6.81ab	8.62bc	12.36	17.85ab	20.32a-d
17.25,23,15	4.10bc	6.56abc	8.70bc	12.28	17.82bc	20.45a-d
34.5,46,10	4.19bc	6.81ab	8.62bc	12.36	17.85ab	20.32a-d
51.75,69,5	3.40d	6.22bc	8.47bc	11.93	16.39b	19.83bcd
69, 92, 20	3.57cd	6.18cd	8.42bc	11.96	17.75bcd	19.72bc
86.25,115,25	4.05bcd	6.67abc	8.49bc	12.15	18.13ab	20.25a-d

103.5,138,30	4.15bc	6.73abc	8.51bc	12.38	17.87ab	20.18a-d
138,184,40	6.16a	7.12a	9.76a	13.00	19.34a	21.47a
F-test	***	**	*	NS	**	*
LSD	0.670	0.606	0.844	1.22	1.474	1.163
CV(%)	13.7	7.8	8.3	8.4	7.0	4.8

* = treatment refers to amount of N and P_2O_5 (kg ha^{-1}) and farmyard manure (t ha^{-1}) applied. Means followed by the same letter within a column are non-significant at P ≤ 0.05 according to Fisher's LSD, NS = non-significant

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Table 2. Effect of integrated FYM and NP fertilizers on sprouting (%) of onion bulbs at ambient condition

	Percent sprouting			
	Storage period (weeks)			
Treatment*	6	8	10	12
0,0,0	1.62c	3.31ef	6.23	11.78bc
0,0,20	1.76bc	3.61c-f	6.37	11.73bc
0, 92, 20	1.78bc	3.57cde	6.56	12.25b
69, 0, 20	2.00ab	3.97a-d	6.75	13.41a
69,92,0	1.98ab	4.04a-d	6.65	13.35a
17.25,23,15	1.76bc	3.82a-d	6.13	12.09b
34.5,46,10	1.62c	3.69b-e	6.50	12.10b
51.75,69,5	1.60c	3.15f	6.11	11.13c
69, 92, 20	1.99ab	4.08abc	6.76	13.58a
86.25, 115,25	2.05ab	4.09ab	6.81	13.61a
103.5,138,30	2.10a	4.15ab	6.82	13.87a
138,184,40	2.11a	4.30a	6.83	14.06a
F-test	**	***	NS	***
LSD	0.310	0.47	0.73	0.74
CV(%)	14.3	10.7	9.6	5.0

* = treatment refers to amount of N and P (kg P_2O_5 ha^{-1}) and farmyard manure (t ha^{-1}) applied. Means with the same letter within a column are statistically non-significant at p ≤ 0.05 according to Fisher's LSD, NS = non-significant

In line with the findings of the present study, high percent weight losses of stored onion bulbs were reported due to nitrogen fertilization (Morsy et al., 2012; Tekalign et al., 2012). Moreover, Kultunov (1984) stated that NPK fertilizers supplemented with FYM resulted in better long term storage of garlic bulbs having lower weight loss. The reason for high weight loss at the higher doses of fertilizer application could be due to the nitrogen(urea) fertilizer which tends to develop soft succulent tissues with high moisture content which predisposes the bulbs to rotting through fungi attach (Rao and Srinivas, 1990). The relatively minimum weight loss of bulbs grown with application of the fertilizers could also be due to higher and continuous uptake of nutrients from organic sources throughout the crop growth period and relatively less moisture as well as higher TSS of bulbs

Percent Sprouting

Sprouting of onion bulbs was significantly affected by the fertilizer treatments (Table 2). Irrespective of pre-harvest treatments, there was a progressive increase in sprouting of onion bulbs with advancement of storage duration which increased from 1.6% at 6 weeks after storage to 14.06 % at 12 weeks of storage (Table 2). The highest sprouting was recorded at the fertilizer combinations of 138 kg N, 184 kg P_2O_5, 40 t FYM ha^{-1} throughout the whole storage period. The minimum sprouting was obtained with application of fertilizer at 51.75 kg N, 69 kg P_2O_5 and 5 t FYM ha^{-1} throughout the whole storage period (Table 2).

Reduced loss due to sprouting with integrated application of NP as well as FYM in the present study could possibly be due to the availability of macro and micro nutrients in optimum amount for better growth and accumulation of dry matter as well as compounds such as Absicic acid (ABA) which is responsible for bulb dormancy. Integrated application of inorganic NP and FYM at optimum amount reduced storage losses of onion bulbs (Anonomous, 1996). Accordingly, Sankar et al. (2005) indicated that combined application of FYM with inorganic fertilizer of 100 percent NPK showed lowest postharvest loss after 120 days storage of onion. The higher rate of increase in bulb sprouting occurred starting from10^{th} week of storage until 12 weeks of storage period, which could be due to the relatively lower temperature prevailing in the study area at the time of the storage. In conformity with the present study, Patil et al. (1986) indicated that maximum bulb sprouting losses were noticed at lower temperature and high humidity during August to November.

Percent Rotting

There was a significant effect of the pre-harvest fertilizer treatments on percent rotting of onion bulbs starting sixth week of storage (Table 3). The maximum percentage of rotted bulbs was recorded from the highest dose of fertilizer treatment, which recorded 12% at the end of 12 weeks of storage period. On the other hand, the lowest percentage of rotting was observed in the control treatment, which recorded 1.27, 3.26, 5.73 and 7.92% at 6, 8, 10 and 12 weeks of storage period, respectively; however, these values did not differ statistically from most of the treatments (Table 3).

Similar findings to the present study was reported by (Anonomous, 1996), where lowest storage losses of onion bulbs were observed in the treatment having FYM at 25 t ha^{-1} with 100:50 NP kg ha^{-1} through chemical fertilizers. Increases in N have also been observed to proportionally increase rotting of shallot bulbs in store (Sebsebe et al., 2010). The highest rotting losses obtained with the highest fertilizer could be due to high moisture content and succulent bulbs attributed by the nitrogen fertilization. The lower rotting percentage at the control treatment could be associated with the lower moisture content and firmness of the bulbs. Besides, optimum amount of integrated NP and FYM significantly reduces rotting losses of bulbs. A beneficial effect of organics in reducing the postharvest rotting has been reported by Patil (1995) in onion and by Suresh (1997) in garlic.

Table 3. Effect of integrated application of FYM and NP fertilizers on percent rotting of onion bulbs under ambient condition

Percent rotting				
Storage periods (weeks)				
Treatment*	6	8	10	12
0,0,0	1.27c	3.26b	5.73c	7.92c
0,0,20	1.65ab	3.96b	6.89b	9.20bc
0, 92, 20	1.61ab	3.92b	6.7bc	9.05bc
69, 0, 20	1.50bc	3.76b	6.51bc	8.68bc
69, 92, 0	1.48bc	3.69b	6.46bc	8.63bc
17.25, 23,15	1.52bc	3.64b	6.38bc	8.52bc
34.5,46,10	1.49bc	3.67b	6.48bc	8.75bc
51.75, 69, 5	1.32bc	3.50b	6.12bc	8.30bc
69, 92, 20	1.43bc	3.60b	6.31bc	8.46bc
86.25, 115, 25	1.53abc	3.78b	6.61bc	8.96bc
103.5,138,30	1.60abc	3.86b	6.81b	9.34b
138,184,40	1.84a	4.96a	8.52a	11.45a

F-test	*	**	***	***
LSD	0.285	0.682	0.891	1.101
CV(%)	16.0	15.4	11.5	10.5

* = treatment refers to amount of N and P_2O_5 (kg ha^{-1}) and farmyard manure (t ha^{-1}) applied. Means with the same letter within a column are statistically non significant at $p \leq 0.05$ using Fisher's LSD.

Table 4. Effect of integrated FYM and inorganic NP fertilization on total soluble solids (%) at ambient conditions

	Total soluble solids (%)						
	Storage period (weeks)						
Treatment*	0	2	4	6	8	10	12
0,0,0	12.73c	13.30d	13.83d	14.64c	15.48c	16.30	16.31
0,0,20	12.80c	13.36cd	13.90d	14.66c	15.76c	16.40	16.53
0, 92, 20	12.90bc	13.36cd	14.00cd	14.70c	15.96bc	16.53	16.66
69, 0, 20	13.3abc	13.7bcd	14.30bcd	15.11bc	15.76c	16.68	16.78
69,92,0	13.40abc	13.80abcd	14.43bcd	15.16bc	15.81bc	16.56	16.66
17.25, 23,15	13.26abc	13.70bcd	14.33bcd	15.06bc	15.96bc	16.53	16.66
34.5,46,10	13.26abc	13.70bcd	14.43bcd	15.20bc	16.21abc	16.53	16.63
51.75,69,5	14.00a	14.43a	15.23a	16.00a	17.03a	17.00	17.40
69, 92, 20	13.80a	14.20ab	14.80ab	15.61ab	16.66ab	16.95	17.08
86.25,115,25	13.70ab	14.06ab	14.60abc	15.44ab	16.96a	16.99	17.35
103.5,138,30	13.36abc	13.86abc	14.36bcd	15.07bcd	15.96bc	16.55	16.71
138,184,40	13.3abc	13.73abcd	14.33bcd	14.97bcd	15.96bc	16.56	16.66
F-test	*	*	**	**	*	NS	NS
LSD	0.704	0.622	0.665	0.658	0.889	0.79	1.94
CV(%)	4.5	3.8	3.9	3.7	4.7	4.1	4.3

* = treatment refers to amount of N and P_2O_5 (kg ha^{-1}) and farmyard manure (t ha^{-1}) applied. Means with the same letter within a column is statistically non-significant at $p \leq 0.05$ according to Fisher's LSD.

Total Soluble Solids (TSS)

Total soluble solids of onion bulbs were significantly affected by pre-harvest fertilizer application until 8 weeks of storage period (Table 4). The total soluble solids increased during 12 weeks storage period which ranged from 12.73% to 17.4%. The maximum total soluble solids content was recorded at fertilizer application of 51.75 kg N, 69 kg P_2O_5, 5 t FYM ha^{-1} throughout the whole storage duration. However, this treatment did not vary statistically with NP and FYM combinations of 69 kg N, 92 kg P_2O_5, 20 t FYM $ha^{-1}$and 86.25 kg N, 115 kg P_2O_5,25 t FYM ha^{-1}. The control treatment recorded the lowest total soluble solids content throughout the whole storage period (Table 4).

Irrespective of treatments, there was a gradual increase in total soluble solids content of the onion bulbs. Many biochemical changes can take place during onion bulb storage such as changes in water, carbohydrate and flavour compound concentration as well as growth regulators (Chope et al*.,* 2006). In line with the findings of the present study, Jawadagi (2011) indicated that combined application FYM and biofertilizers increased TSS content of onion bulbs. These results are also in conformity with the findings of Kukanoor (2005) who observed an increase in TSS levels during storage of onion bulbs. The increase in total soluble solids with the fertilizer application of 51.75 kg N, 69 kg P_2O_5, 5 t FYM ha^{-1} could be due to increased accumulation of important macro and micro nutrients which could be used as a constituent for different carbohydrates and decrease in moisture content of the bulbs. Similarly, Hansen and Henriksen (2001) described that the increase in bulb total soluble solid during storage is due to loss of moisture and gradual hydrolysis of fructans to fructose.

Percent Dry Matter

Significant effect of integrated inorganic NP and FYM application was observed on percent dry matter content of onion bulbs (Table 5). There was a continuous increase in percent dry matter content of onion bulbs until 6 weeks of storage period and thereafter a gradual decrease until the end of storage (Table 5). Percent dry matter was highest at 51.75 kg N, 69 kg P_2O_5, 5 t FYM ha^{-1} throughout the whole storage period. On the other hand, the lowest percent dry matter was recorded in bulbs fertilized with 138 kg N, 184 kg P_2O_5 and, 40 t FYM ha^{-1} (Table 5).

The reason for the loss of dry matter of bulbs with higher N application could be due to the influence of N in increasing the concentration of enzymes and growth promoters which could bring an increased sprouting of onion bulbs with consequent hydrolysis of fructans (Dankhar and Singh, 1991; Peiris et.al., 1997), with eventual increased reduction in bulb dry matter content. Besides, the influence of N fertilization on gibberellic acid (GA) biosynthesis and involvement of GA in regulating the pattern of assimilate partitioning were reported by Yim et al. (1997), where high GA level leads to a higher carbohydrate allocation to the shoots where as low GA level resulted in more dry matter allocation to the roots. In conformity to the findings of the present study, Jawadagi (2011) revealed that percent dry matter content of onion bulbs was significantly affected by pre-harvest integrated fertilizer application.

Pungency of Bulbs

Integrated application of NP and FYM significantly affected pyruvate content of onion bulbs (Table 6). Irrespective of the treatments, increment in pyruvate content of bulbs were observed during the three months of storage period with 12.04 µ mol gm^{-1} tissue at 0 week of storage to 25.19 µ mol gm^{-1} tissue at 12 week storage period. The pyruvate content showed increase with an increased rate of the three fertilizers having the maximum amount recorded at 138 kg N, 184 kg P_2O_5 and, 40 t FYM ha^{-1}. The treatment was however, in statistical parity with most of the treatments except the control which recorded the lowest throughout the whole storage period (Table 6).

Table 5. Changes in dry matter (%) content of onion bulbs subjected to pre-harvest FYM and NP fertilizers

Dry matter (%)							
Storage period (Weeks)							
Treatment*	0	2	4	6	8	10	12
0,0,0	13.13ab	13.70ab	14.92ab	16.09ab	15.83ab	15.30abc	15.21ab
0,0,20	13.13ab	13.72ab	14.56a-d	15.87abc	15.54abc	15.14abc	14.82a-d
0, 92, 20	12.76a-e	13.55ab	14.49a-d	15.85abc	15.73abc	15.36ab	15.07abc
69, 0, 20	12.62cde	13.20bc	14.08def	15.58abc	15.35bcd	15.04bc	14.81a-d
69,92,0	12.61ed	13.41abc	14.25b-e	15.54bcd	15.34bcd	15.10abc	14.77a-d
17.25, 23,15	13.05a-d	13.66ab	14.82a-d	15.93abc	15.72abc	15.37ab	15.02abc
34.5,46,10	13.10abc	13.66ab	14.54a-d	15.70abc	15.49abc	15.16abc	14.78a-d
51.75,69, 5	13.15a	13.80a	14.98a	16.17a	16.00a	15.62a	15.29a
69, 92, 20	12.66b-e	13.34abc	14.04def	15.34cde	15.18cd	14.91bcd	14.68b-e
86.25,115,25	12.53e	13.30abc	14.10c-f	15.44cde	15.17cd	14.81cd	14.62cde
103.5,138,30	12.52e	12.98c	13.58f	14.96de	14.84d	14.50d	14.34ed
138,184,40	12.35	12.96c	13.50ef	14.92e	14.78d	14.45d	14.23e
F-test	**	*	***	**	**	**	**
LSD	0.490	0.536	0.727	0.611	0.578	0.530	0.545

* = treatment refers to amount of N and P_2O_5 (kg ha^{-1}) and farmyard manure (t ha^{-1}) applied. Means with the same letter within a column are statistically non significant at p ≤ 0.05 according to Fisher's LSD.

Table 6. Effect of integrated NP and FYM application on pyruvate content (μ mol gm^{-1}) of onion bulbs stored under ambient condition

	Pyruvate content (μ mol gm^{-1})						
	Storage period (weeks)						
Treatment*	0	2	4	6	8	10	12
0,0,0	12.04c	14.87c	17.58	17.84c	19.05c	22.29	23.73
0,0,20	13.33abc	15.82abc	18.85	19.04bc	20.34bc	23.43	24.70
0, 92, 20	13.11bc	15.72ab	19.09	19.13bc	20.64bc	23.45	24.67
69, 0, 20	13.66abc	16.68ab	19.47	20.27ab	21.94ab	24.25	24.90
69,92,0	13.93ab	16.66ab	19.57	20.29ab	21.96ab	24.20	24.92
17.25, 23,15	13.18ab	15.67bc	19.15	19.64ab	21.56ab	23.48	24.72
34.5,46,10	13.73abc	16.34ab	19.17	20.14ab	21.79ab	23.98	24.85
51.75,69, 5	13.85abc	16.41ab	19.27	20.19ab	21.86ab	24.17	24.85
69, 92, 20	14.82ab	16.99ab	19.80	20.37ab	22.11ab	24.25	24.95
86.25,115,25	14.82ab	17.09a	20.02	20.74ab	22.68a	24.40	25.10
103.5,138,30	15.05a	17.09a	20.07	20.89a	22.86a	24.30	25.10
138,184,40	15.07a	17.11a	20.37	21.02a	23.03a	24.47	25.19
F-test	*	*	NS	*	**	NS	NS
LSD	1.843	1.329	2.80	1.706	1.809	3.19	1.72
CV (%)	11.4	6.9	7.9	7.3	7.1	6.4	6.0

* = treatment refers to amount of N and P_2O_5 (kg ha^{-1}) and farmyard manure (t ha^{-1}) applied.
Means with the same letter within a column are statistically non-significant at P ≤ 0.05(*) according to Fisher's LSD, NS=non-significant

In accordance with the present findings, Yoo et al. (2012), in their studies on biochemical changes during storage of onion bulbs, indicated that pungency of onion bulbs significantly increased with advancement of storage duration. Randle (1998) also indicated that bulb pungency increased significantly with increasing N availability. Similarly, increasing levels of N linearly increased pyruvic acid contents of onion bulbs (Coolong and Randle, 2003). An increasing pungency level of shallot bulbs was observed with increasing N levels (Sebsebe et al., 2010). The increase in pungency with increase in N application could be due to the role of N as constituent of important amino acids and proteins including Allinase enzyme and S-alk(en)yl-L-cysteine sulphoxide (ACSO) compounds (Anderson, 1990; Koprivova et al., 2000).

Percent Marketability

Integrated application of NP and FYM significantly affected percent marketability of onion bulbs (Table 7). Irrespective of treatments, percent marketability decreased drastically during the 12 weeks of storage duration (Table 7). The control treatment recorded minimum marketability of onion bulbs throughout the storage period. There was a drop from 93.59% to 84% within 6 weeks of storage and to 40.47% at 12 week storage duration respectively. On the other hand, the highest percent marketability was recorded at integrated pre-harvest application of 86.25 kg N, 115 kg P_2O_5, 25 t FYM ha^{-1} which recorded 61.51% at the end of storage period, and was in statistical parity with the application of 69 kg N, 92 kg P_2O_5, 20 t FYM ha^{-1} throughout the whole storage period (Table 7).

Table 7. Effect of integrated FYM and inorganic NP on marketable bulb (%) of onion at ambient condition

	Percent Marketability					
	Storage period (weeks)					
Treatment*	2	4	6	8	10	12
0,0,0	93.59c	91.30e	84.99e	75.03e	57.18d	40.47d
0,0,20	96.82ab	95.23cd	90.19cd	81.77cd	67.65bc	51.96c
0, 92, 20	98.41ab	96.67abc	91.99abc	84.54abc	71.50abc	56.01abc
69, 0, 20	96.64ab	95.42bcd	90.71bc	82.68bcd	70.108abc	55.35abc
69,92,0	95.77bc	93.99d	87.90d	80.07	67.01c	53.0bc
17.25, 23, 15	98.2ab	96.54abcd	91.78abc	83.68abc	69.75abc	54.51abc
34.5, 46, 10	98.53a	97.52abc	93.24ab	85.71ab	73.59ab	58.91abc
51.75, 69, 5	98.75a	97.55abc	93.11ab	85.33ab	72.20abc	57.23abc
69, 92, 20	99.04a	97.9ab	93.55a	86.04ab	73.98a	59.92ab
86.25, 115, 25	99.26a	98.48a	94.09a	86.44a	74.25a	61.51a
103.5, 138, 30	98.43ab	97.18abc	92.23abc	83.64abc	69.94abc	54.10bc
138,184,40	98.10ab	96.98abc	92.00abc	83.38abcd	69.96abc	54.15bc
F-test	**	***	***	***	***	***
LSD	2.746	2.652	2.801	3.466	5.404	7.101
CV(%)	2.4	2.3	2.6	3.5	6.6	11.1

* = treatment refers to amount of N and P_2O_5 (kg ha^{-1}) and farmyard manure (t ha^{-1}) applied. Means with the same letter within a column are statistically non significant at $p \leq 0.05$ according Fisher's LSD.

The higher marketability of bulbs obtained with application of optimum doses of integrated nutrient might be due to lower rotting and weight losses recorded by the treatments. In conformity with the present findings, Jawadagi (2011) indicated that combined application of organic FYM and biofertilizers, recorded the highest marketability of onion bulbs while the control recorded lowest throughout four months storage. Similar result has been reported in onion by Madan and Sandhu (1983).

Conclusion

Many studies have revealed that integrated application of nitrogen, phosphorus and FYM significantly improved bulb yields and postharvest quality as well as shelf-life of crops and has been recommended as a means of improving productivity and maintaining sustainability of onion production. Thus, a series of laboratory experiments were conducted to investigate the effect of integrated NP and FYM use on postharvest quality and shelf life of Bombay red onion bulbs. The study revealed that pre-harvest application of nill of the three fertilizers gave lower percent weight loss, sprouting and rotting of onion bulbs although at par with integrated inorganic NP at 69 kg ha^{-1} and 92 kg P_2O_5 ha^{-1} combined with 20 t FYM ha^{-1}, with respect to physiological weight loss and percent rotting of onion bulbs. Besides integrated inorganic NP at 69 kg ha^{-1} and 92 kg P_2O_5 ha^{-1} combined with 20 t FYM ha^{-1} gave highest TSS and pyruvate levels, and marketability although it recorded lower percent dry matter. The control recorded the lowest TSS, pyruvate as well as percent marketability of onion bulbs throughout the whole storage period. Therefore, it can be concluded that integrated application of inorganic NP fertilizers at 69 N kg ha^{-1} and 92 kg P_2O_5 ha^{-1} combined with 20 t FYM ha^{-1} was found to be promising for prolonged postharvest quality and shelf life of onion bulbs in the central rift valley area of the county.

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