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Determination of fertilizer rates and intra-row spacing on yield and yield components of onion (*Allium cepa* L. Var. *cepa*) under irrigation in site zone, Somalia region, eastern Ethiopia

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Abstract
A field experiment was concted in Harwa irrgation station in 2017/18 to assess effect nitrogen fetlizer to observe and intra-row spacing on yield and yield components of Adama Red onion (*Allium cepa* L.) experiment observe the effect of six N rates (0, 46, 69, 92, 115 and 138 kg ha-1) and four intra-row spacing levels (7.5, 10 12.5 and 15 cm) on yield and yield components of onion (Allium cepa L.). Was laid out according to randomized complete block design in factorial arrangement with three replications. Results revealed that the interaction effects of N rates and intra-row spacing showed highly significant (P<0.01) effect on harvest index, fresh biomass yield, dry biomass yield, total bulb yield and marketable bulb yield.
The interaction effects of intra-row spacing and farmyard manure rates showed significant influence on biological, total, marketable and unmarketable bulb yields. Highest total bulb yield, 58.74 t ha-1 and marketable bulb yields 57.77 t ha-1 were obtained from plants spaced at 7.5 cm and plots received 30 t ha-1 farm yard manure. The highest weight loss and bulb rotting were observed at wider intra-row spacing (15 cm) and highest farmyard manure application, which was 30 t ha-1. Intra-row spacing of 7.5 cm and 20 the harvest index, fresh biomass yield total bulb yield marketable bulb yield. thus according to pant to plant was found best treatment than others in relation to yield to yield rate gave good marketable bulb yield and better storage life under the study area.

Keywords: Allium cepa bulb yield, nitrogen intra-row spacing, yield component irrigation, storage life

Introduction

Onion (*Allium cepa* L.) belongs to the genus *Allium* of the family *Alliaceae*, which is originated in southwest Asia and the Mediterranean regions and they are typically plants of open, sunny, dry sites in fairly arid climates, however many species are also found in the steppes, dry mountain slopes, rocky or stony open sites, or summer dry, open, scrubby vegetation (Hanelt, 1990) [25]. Onions exhibit particular diversity in the eastern Mediterranean countries, through Turkmenistan, Tajikistan to Pakistan and India, which are the most important sources of genetic diversity and believed to be center of origin (Astley *et al.*, 1982; Brewster, 2008) [6, 8].

Onion is considered as one of the most important vegetable crops produced on large scale in Ethiopia and occupies economically important place among vegetables in the country (MoARD, 2009) [34]. The area under onion is increasing from time to time mainly due to its high profitability per unit area, ease of production and the increases in small scale irrigation areas. Despite the increase in cultivated areas, the productivity of onion is much lower than other African countries and the world average. The low productivity could be attributed to the limited availability of quality seeds and associated production technologies used (Lemma and Shimeles, 2003) [32]. According to Central Statistics Agency (2013) [11], for private farmers' holdings in '*Meher*' season 2012/2013, the total area coverage by onion crop in the country was 21,865.4 ha, with total production of 219,188.6 t with average productivity of 10.02 t ha^{-1}. This is very low yield compared to the world average of 19.7 t ha^{-1} (FAO, 2012) [18]. The low yield level could be due to low soil fertility, salinity effect and inappropriate cultural practice (MARC, 2004) [33].

The use of appropriate agronomic management has an undoubted contribution in increasing crop yield. One of the important measures to be taken in increasing the productivity of onion is to determine the optimum amount of fertilizers rates and spacing in each agro-ecology. Among the fertilizers, N containing ones is the most important, since it is being a component of amino acids and chlorophyll, promotes rapid vegetative growth, protein content and yield of the crop (Lemma and Shimeles, 2003) [32]. According to Upper Awash Agro-Industry Enterprise (2001) [41] report it is very difficult to give general recommendation for onion production that can be applicable to different agro ecological zones of the country. Gupta *et al.* (1994) [23] explain also to optimize onion productivity, full package of information is required for each growing region of the country.

Farmers in the Gode area are mostly engaged in livestock production and few have recently started sedentary agriculture through the help of government in establishing settlements and awaring irrigation system. Thus, productivity of most of the crops, including onion, is low due to poor agronomic and management practices. Moreover, lack of improved varieties and seed, absence of recommended N fertilizer rate and plant spacing are the pertinent problems of the study area. Currently the nationally recommended fertilizer rate of 100kg DAP ha^{-1}(46 kgP_2O_5 ha^{-1}) and 150 kg Urea ha^{-1} in split application are used along with 10cm plant spacing for onion production with no consideration of soil types (EARO, 2004; Lemma and Shimeles, 2003) [17, 32].

However, farmers in the Gode area have no experience of applying the nationally recommended fertilizer rate and plant spacing rather they randomly practice undetermined fertilizer rate and plant spacing. In view of these, the present study was initiated to find out optimum and economic rates of fertilizer and intra-row spacing of onion crop for Gode province.

Materials and Methods

Description of the Study Area

A field study was conducted in 2014 from January to June under irrigation at Adegala Agriculture irrgation on farm. in Somali National Regional State, South-eastern Ethiopia. The site is situated at latitude of 5°57'N and longitude of 43°27'E (Figure 1). The experimental site lies at an altitude of about 300m above sea level. Adegala is characterized by high temperature, erratic rainfall, sandy clay loam soil texture and has a vast area of plain suitable for large scale irrigated agriculture and livestock production (Ayele, 2005) [4].

Description of the Experimental Materials

Onion cultivar called *Seiyunn-Hadhramout-R.Y* (Yemen F_1-hybrid seed), locally named as '*Qalafo*' onion, which is well adapted and widely cultivated in the study area was used as a test crop for the experiment. It has light red colour, site Adegala shaped bulb with pungent smell and mature in 115 -130 days. Its yield potential is 35-46 t ha^{-1} (personal communication April, 2013). Urea (46% N) fertilizer was used as a source of N for the experiment. The national recommended rate of N fertilizer which was found adequate for dry bulb production in upper awash region was 92kg N ha^{-1} and 10cm plant spacing was also investigated at Melkassa and Werer Research centers (Lemma and Shimeles, 2003) [32] and they were used as the basis to set the N fertilizer rates and intra- row spacing in this study.

Treatments and Experimental Design

The treatments were consist of factorial combination of six rates of N fertilizer (0, 46, 69, 92, 115 and 138 kg ha^{-1} and four levels of intra-row spacing (7.5, 10, 12.5, and 15cm). There were a total of 24 treatment combinations. The experiment was laid out in randomized complete block design (RCBD) with three replications. The size of each plot was 2x3m^2 accommodating ten rows (five double rows) with 40, 30, 24 and 20 plants per row for the intra-row spacing of 7.5, 10, 12.5 and 15cm, respectively. The recommended inter-row spacing of 40cm was maintained for all plots. The distance between plots and blocks were 1m and 1.5m, respectively. The outer single rows at both sides of the plot and one plant at both ends of the rows were considered as border plants. Internal single rows of the outer double rows at both sides of the plot were used for destructive samples (harvest index). The remaining plants in the six central rows were used to determine yield per plot which was converted to t ha^{-1}.

Experimental Procedure

Seedlings were raised on three sunken beds (each 1.2 x 5m^2) from Yemen produced seed locally named as '*Qalafo*' onion. Seeds were obtained from shop of vegetable seed supplier and were sawn on January 01, 2013 at 10cm distance between rows, lightly covered with soil and mulched with grass (until seedlings are emerged 2-5cm from the soil). Seedlings were managed for six weeks and then after transplanted, when they reached 12-15cm height or 3-4 true leaves stage, to the main experimental plots and one day before transplanting the seedlings were irrigated for safe uplifting. During transplanting only healthy, vigorous and uniform seedlings grown at the center of seedbeds were transplanted and gap filling was done within a week after transplanting.

The experimental field was ploughed and harrowed by tractor. Large clods were broken down in order to make the land fine tilth, and plots were leveled and furrows and ridges were prepared at a spacing of 40cm.The experiment was conducted under furrow irrigation method. Four day irrigation interval was maintained for the 1st four weeks and then extended to seven days interval until 15 days to harvest, when irrigation was stopped completely. All other agronomic practices were applied as per the recommendation made for the crop for all plots throughout the experimental period. Harvesting of onion bulbs was done when 70% plants in each plot show neck fall and harvested onion bulbs were cured for four days by windrowing on the ground before topping (EARO, 2004) [33].

Days to maturity

Days to maturity were the actual number of days from the transplanting to the time when 70% of plants' foliage collapses.

Plant height and leaf length (cm)

Plant height was measured by a ruler in centimeters from the soil surface to the tip of the matured leaf; and leaf lengths were taken from three leaves $plant^{-1}$ at maturity.

Leaf number $plant^{-1}$

This refers to the mean number of leaves produced by sampled plants. The total number of leaves of sampled plants was counted and divided by the number of plants to get mean leaf numbers $plant^{-1}$.

Neck thickness (cm)

The average neck thickness was measured at the narrowest point at the junction of bulb and leaf sheath by using verner caliper.

Bulb length and bulb diameter (cm)

The average heights of the matured bulb length and bulb diameter at the widest point in the middle portion of the matured bulb were measured by using vernier caliper.

Soil Sampling

Soil sampling was done before transplanting of seedlings from five entire representative points of the experimental site from depth of 0-30cm then mixed to form composite sample. The composite sample was sub-divided into working samples for analysis. Soil analysis for specific parameters was carried out at soil laboratories of Addis Ababa city government environmental protection authority and water works design and supervision enterprise. The composite pre-planting soil samples were analyzed for soil EC and pH at 1:2.5 soils to water ratio using a glass electrode attached to pH digital meter, organic matter was determined by using Walklay and Black (1934) [42] method, total N was determined using Kjeldhal method as described by Dewis and Freitas (1975) [12], available P was determined by the methods of Olsen and Dean (1965) [39], exchangeable K and Na was determined by potentiometericaly with 1M ammonium acetate at pH 7.0, Soil cation exchange capacity (CEC) was determined by ammonium acetate method (Cottenie, 1980) [10] and soil texture was determined by Bouyocous hydrometer method (Moodie *et al*., 1954) [37].

Data Collection

Yield and yield component traits were collected from 10 randomly selected and pre-tagged plants from the six central rows of each plot. Bulb yield was registered from plants grown in the six central rows of each plot. Data were collected as per the procedures mentioned as follows.

Table 1: Intra-row spacing and FYM on biological yield, total bulb yield, marketable bulb yield and unmarketable.

Spacing (cm)	Treatments FYM (tha^{-1})	Biological yield (g/plant)	Total bulb yield ($t\ ha^{-1}$)	Marketable bulb yield ($t\ ha^{-1}$)	Unmarketable bulb yield ($t\ ha^{-1}$)
7.5	0	94.93^{i}	37.53^{cde}	36.36^{cdef}	1.17^{b}
	10	104.06^{gh}	39.81^{cd}	38.23^{cde}	1.59^{a}
	20	110.23^{fgh}	54.34^{ab}	53.59^{ab}	0.74^{d}
	30	100.94^{hi}	58.74^{a}	57.77^{a}	0.97^{bc}
10	0	111.17^{fgh}	32.68^{cd}	38.88^{cde}	0.80^{cd}
	10	103.22^{hi}	32.24^{def}	31.09^{defg}	1.15^{b}
	20	119.75^{ef}	46.88^{bc}	46.25^{bc}	0.63^{de}
	30	111.79^{fgh}	39.41^{cd}	38.35^{cde}	1.05^{b}
12.5	0	111.05^{fgh}	28.03^{ef}	27.28^{fg}	0.75^{d}
	10	129.32^{cde}	41.92^{cd}	41.72^{c}	0.20^{f}
	20	139.93^{abc}	40.40^{cd}	39.68^{cd}	0.72^{de}
	30	134.72^{bcd}	39.95^{cd}	39.79^{cd}	0.16^{f}
15	0	117.58^{efg}	24.43^{f}	23.91^{g}	0.52^{e}
	10	147.07^{ab}	37.04^{cde}	36.82^{cdef}	0.22^{f}
	20	125.97^{de}	29.32^{ef}	29.05^{efg}	0.27^{f}
	30	151.96^{a}	36.69^{de}	36.56^{cdef}	0.13^{f}
LSD (5%)		13.69	10.17	10.25	0.67
SEM+		4.70	3.49	3.51	0.07
CV (%)		6.87	15.58	15.97	16.65

LSD least significant difference, SEM=standard error of mean; CV= coefficient of variation; FYM= farmyard manure. Means followed by the same letter are not significantly different at P< 0.05.

Fresh biomass yield (g plant^{-1}): was recorded as the sum of the fresh weight above ground parts and bulbs of sampled plants taken as soon as the crop was harvested at maturity. Then the average fresh biomass yield per plant was calculated and recorded.

Dry biomass yield (g plant^{-1}): was recorded as the sum of dry weight of above ground parts and bulbs of sampled plants taken after oven drying to a constant weight is attained. The average biological yield of sampled plants was calculated and recorded as dry biological yield per plant.

Total bulb yield (t ha^{-1}): total bulb yield was measured as the total weight of both marketable and unmarketable bulbs produced by all plants at central six rows per plot. The total weight of the bulbs were measured using digital balance after curing and it was converted into t ha^{-1}.

Harvest index (%): refers to the ratio of bulb dry weight to total dry biomass of a plant and were calculated as:

$$\text{Harvet Index}(\%) = \frac{\text{bulb dry wight}}{\text{total dry biomass}}\ x\,100$$

(1988). the following were computed and used to estimate the cost and benefits of different treatment combinations.

Gross average bulb yield (kg ha^{-1}) (AvY): is an average yield of each treatment.

Adjusted yield (kg ha^{-1}) (A_jY): is the average yield was adjusted downward by a 15% to reflect the difference between the experimental yield and yield of farmers. This is due to, under experimental condition there was optimum plant population, better crop management and small plot size.

$$A_jY = A_vY - (A_vY * 0.15)$$

Total cost: is the cost of fertilizer used for the experiment. The price was based on price during planting. The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding, crop protection, and harvesting were assumed to remain the same or the difference were insignificant among treatments.

Marketable bulb yield (tha^{-1}): marketable bulb yield was the yield recorded from all plants in the central six rows per plot and was converted to yield of of t ha^{-1} which were greater than 3 cm in diameter (Morsy *et al*., 2012) [38]. The marketable bulb yield weight standared for Ethiopia is grouped as oversized (above 160g), large (100-160g), medium (50-85g), smaller sized (21-50g) (Lemma and Shimeles, 2003) [32].

Unmarketable yield (tha^{-1}): was recorded as the total weight of damaged, physiological disordered, discolored, pest damaged, splitted, thick necked, rotten and small bulbs (below 20g) after curing that are discarded as unmarketable bulb (Lemma and Shemels, 2003; Morsy *et al*., 2012) [32, 38].

Data Analysis
The data were subjected to analysis of variance (ANOVA) using SAS version 9.1 GLM procedures and least significant difference (LSD) was used to separate means at p<0.05 probability levels of significance.

Economic Analysis
Partial budget analysis was employed for economic analysis of fertilizer application and plant spacing which was carried out for combined bulb yield data. The potential response of crop towards the added fertilizer and plant spacing was estimated where price of fertilizers and other costs during planting ultimately determined the economic feasibility of fertilizer application and plant spacing treatments. The economic analysis was computed using the procedure described by CIMMYT
Gross benefit = Adjusted yield * unit price **Net benefit** = Gross benefit – total cost

$$\text{Cost Benefit Ratio}(\%) = \frac{\text{Change in net benefit}}{\text{change in total cost}} \times 100$$

Results and Discussion
Selected Soil Physico-chemical Properties of the Study Area
The results of the laboratory analysis of some selected physico-chemical properties of the soil of experimental site are presented below (Table 1). Results of the soil analysis before planting showed that the soil of the site is sandy clay loam in texture with alkaline (pH 8.3) reaction. The soil had a bulk density of 1.08g cm^{-3}, and 0.02%, 29.34ppm, 0.70% of total N, available P and, organic matter content, respectively. It had also 0.40%, 14.6c.mol kg^{-1} soil, 0.729dSm^{-1}and0.70c.mol kg^{-1} of organic carbon, CEC, EC, and exchangeable Sodium respectively. The rating under remark (Table 1) was done according to Hazelton and Murphy (2007) [26] and Donald *et al*. (2011) [13] suggestions.

Days to maturity and leaf number
The influence of intra-row spacing revealed significant variation (p<0.05) on maturity of onion and leaf number while farm yard manure (FYM) and their interaction did not show significant differences (Table 1). Closer plant spacing enhanced maturity (116.17 days) while wider plant spacing (15 cm) showed slightly delayed maturity. Maximum leaf number $plant^{-1}$ (13.17) was obtained from plants spaced at 15 cm followed by those spaced at 12.5 cm intra-row spacing. On the other hand, 7.5 cm spaced plants gave the minimum number of leaves $plant^{-1}$ (11.29) that did not vary statistically from plants spaced at 10 cm apart, which gave 11.65 leaves $plant^{-1}$. Wider spacing that allowed plant to have access to more nitrogen which prolonged maturity and higher number of leaves. While in closer spacing, plant competes for light, nutrient and moisture causing early bulb maturity and reduced leaf number (Brewster, 1990, 1994) [25]. Brewster (1994) and Belay *et al*. (2015) noted that bulb maturity was advanced by higher planting density, which was associated with a high leaf area index and hence high light interception by the leaf canopy that advanced the date of bulb scale initiation.

Yield and Yield Related Traits
Fresh biomass yield
The highest fresh biomass yield (125.18g $plant^{-1}$) was obtained from the combined effect of 138kg N ha^{-1} and wider intra-row spacing of 15cm, which was higher by

Table 2: Soil physico-chemical properties of the experimental site before planting

Soil properties	Results	Remark
Soil depth(cm)	0-30	
Particle size distribution (%0-)		
Clay (%)	23.08	
Silt (%)	25.84	
Sand (%)	51.08	
Soil textural class		Sandy clay loam
Bulk density (g/cm^3)	1.08	Satisfactory/ moderate
Organic carbon (%)	0.40	Low
Organic matter content (%)	0.70	Low
Total Nitrogen (%)	0.02	Very Low
Available Phosphorus (ppm)	29.34	High
CEC (c.mol/kg soil)	14.6	Moderate
Exchangeable Sodium (c.mol kg^{-1})	0.70	Moderate
EC (dS m^{-1})	0.729	slightly saline
Soil pH	8.3	Alkaline

Source: Addis Ababa city government environmental protection authority and water works design and supervision enterprise soil laboratories.

About 90% over the fresh biomass yield per plant recorded from treatments of null N fertilizer application combined with 7.5cm intra-row spacing (Table 2). The increased fresh biomass yield per plant at higher rate of N and wider spacing might be due to increased leaf growth which favoured accumulation of more assimilates in the bulbs thereby increasing bulb length, bulb diameter and mean bulb weight, root and vegetative growth which contributed to fresh biomass yield of onion plants increased at higher N and wider intra-row spacing due to the availability of sufficient growth factors that permit the plants to accumulate more assimilates. Particularly the increased N rates might have stimulating effect on vegetative and root growth development as well as uptake of other nutrients which leads to higher fresh biomass production (Marschner, 1995) [35]. In contrast to this, if the N is deficient in plants, even optimal amounts of P and K and other elements in the soil cannot be utilized efficiently which in turn may lead to the production of low biomass by the crop (Brady and Weil, 2002) [7].
The result of this study is supported by Halvorson *et al*. (2002) [24] who reported that higher N application rates lead to rapid leaf

area development, prolonged the life of leaves, improved leaf area, and increased overall crop assimilation which in turn contribute to the increased fresh biomass yield of the crop. This finding is also in conformity with the finding of Dereje *et al*. (2012) [15] who reported that shallot bulbs planted at 20cm intra-row spacing grow more vigorously and obtained more biological yield per plant than those planted at 10cm spacing. Other authors (Khan *et al*., 2002; Akuon, 2004) [30, 1] also reported that the increased bulb weight and above ground vegetative parts of onion were obtained from plants grown in wider spacing and higher rates of N application which ultimately increased the fresh biomass yield of onion.

Dry biomass yield

The highest dry biomass yield (30.39g plant^{-1}) was obtained from the combined effect of 138kg N ha^{-1} and wider intra-row spacing of 15cm, which was about 217.52% higher over the dry biomass yield per plant recorded from null N fertilizer application and closer intra-row spacing of 7.5cm (Table 2). The general trend for dry

Table 3: Interaction effects of nitrogen rates and intra-row spacing on harvest index (%), fresh and dry biomass (g plant^{-1}) and bulb yield (t ha^{-1}) of Qalafo onion variety grown at Godeunder irrigated condition

N (kg ha^{-1})	Spacing (cm)	Fresh biomass yield (g)	Dry biomass yield (g)	Total Yield (tha^{-1})	bulb Marketable bulb yield (tha^{-1})	Harvest index (%)
0	7.5	65.68^{n}	8.18^{p}	27.98^{i}	19.89^{i}	79.02^{a}
	10	65.84^{n}	8.34^{p}	21.07^{mn}	17.99^{l}	75.21^{ab}
	12,5	66.58^{n}	9.08^{op}	17.15^{o}	14.10^{m}	72.64^{a-d}
	15	67.58^{n}	10.08^{nop}	14.62^{p}	11.62^{n}	70.04^{a-e}
46	7.5	76.05^{m}	10.40^{nop}	31.80^{fg}	29.61^{gh}	69.34^{a-e}
	10	77.02^{m}	11.37^{mno}	24.33^{k}	22.16^{j}	61.14^{c-i}
	12,5	77.58^{lm}	11.93^{lmn}	19.69^{n}	17.53^{l}	59.95^{d-i}
	15	79.85^{l}	14.20^{jkl}	17.17^{o}	15.03^{m}	52.55^{g-k}
69	7.5	83.29^{k}	12.54^{lmn}	35.06^{e}	32.93^{f}	63.90^{b-g}
	10	84.20^{jk}	13.45^{klm}	26.75^{ij}	24.63^{i}	62.88^{c-i}
	12,5	86.21^{j}	15.46^{ijk}	22.20^{lm}	20.10^{k}	59.59^{e-i}
	15	90.99^{i}	20.24^{ef}	20.10^{n}	18.02^{l}	50.43^{h-k}
92	7.5	94.97^{h}	17.12^{ghi}	41.91^{c}	39.96^{c}	49.69^{ijk}
	10	96.83^{h}	18.98^{fg}	32.37^{f}	30.43^{g}	48.85^{ijk}
	12,5	99.68^{g}	21.83^{cde}	27.03^{i}	25.16^{i}	46.58^{jk}
	15	100.78^{g}	22.93^{cd}	22.89^{l}	21.10^{jk}	45.16^{jk}
115	7.5	104.31^{f}	19.46^{efg}	47.83^{b}	46.28^{b}	55.62^{f-j}
	10	105.20^{f}	20.35^{def}	36.31^{e}	34.82^{e}	53.86^{f-k}
	12,5	106.87^{ef}	22.02^{cde}	29.72^{h}	28.34^{h}	52.18^{g-k}
	15	108.96^{de}	24.11^{bc}	25.46^{jk}	24.19^{i}	50.43^{h-k}
138	7.5	111.04^{cd}	16.25^{hij}	52.04^{a}	50.88^{a}	73.91^{abc}
	10	113.46^{c}	18.67f^{gh}	40.24^{d}	37.59^{d}	66.16^{b-f}
	12,5	120.72^{b}	25.93^{b}	35.10^{e}	34.24^{ef}	51.39^{g-k}
	15	125.18^{a}	30.39^{a}	30.74^{gh}	29.99^{gh}	41.62^{k}
LSD (5%)		2.64	2.64	1.39	1.68	12.79
CV (%)		1.75	9.58	2.91	3.76	13.29

Means values in columns and rows followed by the same letter are not significantly different at $P< 0.05$, LSD = least significant difference; CV= coefficient of variation in percent.

Biomass yield per plant was observed increasing as the N rate and spacing between plants increased due to the fact factors which affected fresh biomass yield similarly affected dry biomass yield. This can be justified by the observed highly significantly association of dry biomass yield with most of bulb characters and above ground growth characters of onion.

The result obtained in this study is supported with the results reported for the major onion dry biomass components such as dry matter weight of bulb. Kumar *et al*. (1998) [31], and Yadav *et al*. (2003) [43] reported that the highest bulb dry weight was obtained at the rate of 150kg N ha^{-1}. Dereje *et al*. (2012) [15] also observed that shallot bulbs planted at 20cm intra-row spacing produced greater bulb dry weight per plant than those planted at 15 and 10cm intra-row spacing. Many other authors (Akuon, 2004; Halvorson *et al*. 2002 and Khan *et al*. 2002) [1, 24, 30] who support this result by explaining as increased fresh biomass yield was due to increased N rates, spacing between plants and the interaction of these factors.

Total bulb yield

The highest total bulb yield (52.04t ha^{-1}) was obtained from the combined application of 138kg N ha^{-1} and closer spacing of 7.5cm, followed by 115kg N ha^{-1} and 7.5cm intra-row spacing which resulted in total bulb yield of 47.83t ha^{-1}. The lowest total bulb yields of 14.62 and 17.15t ha^{-1} were produced by plants which were planted at wider intra-row spacing of 15 and 12.5cm, respectively, without N fertilizer application. It was observed that the total bulb yield was increased as the level of applied N and plant density increased. This might be due to the fact that supplying N increases the rate of metabolism in plants where more carbohydrate is synthesized which increases the bulb weight and thus increases total yield with optimum plant population.

The increased total bulb yield in closer spacing than wider spacing might be attributed to the increased number of bulbs per unit area while the higher rate of N increases the uptake of readily available nutrients which enhance growth and thereby improve assimilate portioned to the storage organ, the bulb (DEFRA, 2002; Eifediyi *et al*., 2010) [14, 16]. Kumar *et al*. (1998) [31] also reported that the closer plant spacing produce higher onion bulb yield. Similarly many other researchers (Jilani *et al*., 2010; Mohanty and Prusi, 2001) [27, 36] reported that increased plant population density proportionally increased yield per unit area in onion.

Marketable bulb yield

The marketable bulb yield followed similar response to that of the total bulb yield. Thus, the highest marketable yield (50.88t ha^{-1}) was obtained in treatments which received the combined application of 138kg N ha^{-1} with closer spacing of 7.5cm, followed by 115kg N ha^{-1} and 7.5cm intra-row spacing. The lowest marketable bulb yield was recorded from treatments treated with null N fertilizer application and 15cm intra-row spacing (11.62 t ha^{-1}) followed by 12.5cm intra-row spacing in the same N level (14.10t ha^{-1}) (Table 2).

The increased marketable bulb yield in closer spacing than wider spacing might be attributed to increased number of bulbs with marketable size per unit area while the higher rate of N increased the uptake of readily available nutrients which enhance growth and thereby improved assimilate portioned to the storage organ, the bulb (DEFRA, 2002; Eifediyi *et al*., 2010) [14, 16]. This result is in accord with Kahsay *et al.* (2013) [28] who reported that highly significant (P<0.001) differences among the levels of intra-row spacing in which the increase of intra-row spacing from 5 to 10cm decreased marketable bulb yield from 34.49 to 28.10t ha^{-1}. Similar result had been forwarded by Seck and Baldeh (2009), Kantona *et al.* (2003) [29] who reported that plant density has an impact on marketable bulb size and the higher the plant density the smaller the marketable bulb size. This result is in contradict to Aliyu (2008) [3] who reported that significantly higher cured bulb yield was recorded with 15cm intra row spacing than other spacings at all levels of N including control.

Unmarketable bulb yield

Unlike other bulb and biomass yield parameters, unmarketable bulb yield was highly significantly (P<0.001) affected only by the main effect of N fertilizer rates. Unmarketable bulb yield significantly decreased in response to increasing N fertilizer application. The highest unmarketable bulb yield (3.05t ha^{-1}) was recorded from onion plants supplied with null N rate followed by 46kg ha^{-1} N which was statistically in par with 69 and 92kg N ha^{-1}. Lowest unmarketable bulb yield (1.36t ha^{-1}) was observed in plots supplied with 138kg N ha^{-1} which was at parity with 115 and 92kg N ha^{-1}, respectively (Table 3). The lower unmarketable yield in higher N rates might be attributed to less competition for nutrients which results in larger bulbs which are marketable.

Table 4: Partial budget, N rates by intra-row spacing experiment

Treatments N (kg ha^{-1})	Spacing (cm)	Average Yield (t ha^{-1})	Adjusted Yield (t ha^{-1})	Gross field (Birr ha^{-1})	Total cost that (Birr ha^{-1})	Net benefit (Birr ha^{-1})	Cost Benefit Ratio (Birr)
0	7.5	23.08	19.62	137,346	35,182.3	102,164	3.90
	10	20.79	17.67	123,720	30,995.2	92,725	3.99
	12.5	17.14	14.57	101,983	25,462.0	76,521	4.00
	15	14.26	12.12	84,860	21,220.5	63,640	3.99
46	7.5	24.11	20.49	143,474	37,859.3	105,615	3.79
	10	24.13	20.50	143,554	36,706.9	106,847	3.91
	12.5	19.69	16.74	117,175	30,146.0	87,029	3.89
	15	17.17	14.59	102,023	26,367.1	76,552	3.90
69	7.5	35.06	29.80	208,607	52,911.6	155,695	3.94
	10	26.75	22.74	159,163	40,793.1	118,369	3.90
	12.5	22.20	18.87	132,106	34,082.0	98,024	3.87
	15	20.09	17.08	119,575	30,857.4	88,718	3.87
92	7.5	41.92	35.63	249,398	62,573.7	186,824	3.98
	10	32.37	27.51	192,582	48,823.1	143,759	3.94
	12.5	27.03	22.98	160,832	41,072.9	119,760	3.92
	15	22.89	19.46	136,215	35,172.0	101,043	3.87
115	7.5	47.83	40.65	284,582	70,994.6	213,587	4.00
	10	36.31	30.87	216,074	54,655.0	161,419	3.95
	12.5	27.72	25.26	176,834	45,246.1	131,588	3.91
	15	25.46	21.64	151,513	39,189.4	112,324	3.86
138	7.5	52.04	44.24	309,664	77,178.6	232,486	4.01
	10	40.23	34.21	239,458	60,462.8	178,995	3.96
	12.5	35.10	29.84	208,845	52,964.3	155,881	3.94
	15	30.74	26.13	182877	46,764.1	136,112	3.91

Price of Urea-11 ETB kg^{-1}, urea fertilizer transportation cost = 0.4 ETB kg^{-1}; labour cost= 60 ETB per person per day; onion harvesting, curing and topping =1.20 ETB kg^{-1}; Sale price of onion= 7 ETB kg^{-1}, Bagging and bagging material cost = 0.05 ETB kg^{-1}, product transportation cost = 0.3 ETB kg^{-1}. (Source: Gode City Administration Finance and Economics Office)

The current study result is in agreement with the result of AL-Moshileh (2001) [2] who observed that application of 150kg N ha^{-1} reduced the unmarketable yield as compared with the control. Syed *et al*. (2001) [40] and Ghaffoor *et al*. (2003) [22] also indicated that the control gave significant maximum unmarketable yield, while minimum unmarketable yields were associated with high rates of N. Generally, maximum unmarketable yields were recorded in plots of null N application. This might be ascribed mainly to N deficiency and sub-optimal growth of the onion plant which in turn resulted weaker plants prone to disease and other biotic and abiotic stresses as well as low assimilate produced, resulting in lower weight of bulbs (Kahn *et al*., 2002).

Bulb sprouting

Significant differences in sprouting bulbs were not observed between intra-row spacing, FYM rate and their interactions. Sprouting of bulbs was not observed until 8th weeks of storage. Absence of bulb sprouting at early stage could be attributed to the high temperature, low relative humidity, curing treatment which inhibits sprouting. Inherent characters of dormancy based on equilibrium of inhibitors in onion bulbs can be affected by temperature where lower and higher temperatures increase the dormant state of onion bulbs and moderate (10-15°C) temperature enhanced the sprouting by breaking dormancy (http://www.nhrdf.com). No sprouting occurs at storage temperature between -1 and 1°C or between 25 and 30°C (Miedema, 1994). But at 10th and 12th weeks of storage period, bulb sprouting was observed.

Table 5: Effects of intra-row spacing and FYM rate on cumulative weight loss (%) of onion bulbs during storage period.

Treatment Spacing (cm)	Storage weeks					
	2nd	4th	6th	8th	10th	12th
7.5	5.20	10.01b	14.50	18.35b	21.32b	23.66c
10	5.30	10.07b	14.51	18.52b	21.52b	23.77c
12.5	5.35	10.38b	15.90	19.21b	22.46b	25.02b
15	5.59	11.66a	16.08	21.41a	24.41a	26.88 a
LSD (5%)	ns	1.02	ns	1.41	1.22	1.19
FYM (t ha^{-1})						
0	4.86	9.92	14.44	18.61	21.52b	23.98b
10	5.42	10.61	14.60	19.02	22.10b	24.78ab
20	5.57	10.83	15.98	19.69	22.73ab	24.79ab
30	5.61	10.85	16.06	20.00	23.34a	25.78a
LSD (5%)	ns	ns	ns	ns	1.2233	1.191
SEM+	0.29	0.37	0.56	0.48	0.42	0.43
CV (%)	16.94	11.57	12.49	8.76	6.54	5.75

LSD = Least significant difference; SEM = standard error of mean; CV= coefficient of variation; FYM = farmyard manure; ns = no significant difference at $p<0.05$. Means followed by the same letter/s within a column are not significantly different at $P< 0.05$.

Harvest index

The highest harvest index (79.02%) was obtained from null N combined with closer spacing of 7.5cm, which is about 37.4% higher over the harvest index recorded from 138kg N ha^{-1} combined with wider spacing of 15cm intra-row spacing (Table 2). The lower harvest index at the wider spacing might be due to the production of more vegetative parts, which might had diverted assimilate number of leaves. While in closer spacing, plant competes for light, nutrient and moisture causing early bulb maturity and reduced leaf number (Brewster, 1990, 1994) [25]. Brewster (1994) and Belay *et al*. (2015) noted that bulb maturity was advanced by higher planting density, which was associated with a high leaf area index and hence high light interception by the leaf canopy that advanced the date of bulb scale initiation.

Away from the economically important part i.e. bulbs. This might be due to the reduced vegetative biomass as compared to the relative higher weight of economic yield of the crop which resulted higher harvest index. The reduction in harvest index at higher rate of N and wider spacing might be due to the total biomass increased more than the economic yield of the crop in response to the combined application of N fertilizer and increased intra-row spacing which might not be associated with a decrease in total bulb yield. Gawronska *et al*. (1984) stated a supportive idea as although harvest index is commonly used as a key plant parameter, it may not necessarily correlate with high yield. This is possible where the applications of mineral nutrients enables onion crop to exhibit a high rate of assimilate production and maintain active growth later in the season.

Economic Analysis

The partial budget analysis revealed that net benefit of Birr 232,486.00 ha^{-1} was obtained from treatment received 138kg N ha^{-1} planted at 7.5cm intra-row spacing followed by the same spacing combined with 115kg N ha^{-1} and the control plot which resulted in Birr 213,587.00 and 102,164 respectively. However, the lowest net benefit was obtained from treatment received null N at 15 cm intra-row spacing (Table 4). High net benefit from the foregoing treatments could be attributed to high yield and the low net benefit was attributed to low yield. Thus, 138kg N ha^{-1} combined with 7.5cm intra-row spacing could be recommended as a first alternative and 7.5cm combined with 115kg N ha^{-1} and 12.5cm combined with null N could be recommended as 2nd and 3rd alternatives, respectively according to the analysis result.

Recommended input combinations should result in maximum possible return with possible minimum cost. Therefore, considering the increments of yield and quality at 7.5cm combined with 138kg N ha^{-1}, which resulted proportional profit with both (115kg N ha^{-1} combined with 7.5cm and null N combined with 12.5cm) could be recommended as best alternative.

Conclusion

Onion is among the most widely cultivated vegetable crops in Ethiopia and is rapidly becoming popular both by producers and consumers. However, lack of improved varieties and production practices have been the major difficulty of onion production and productivity in the country. Results of the field experiment revealed that the main effects of N rates and intra-row spacing showed a significant effect on unmarketable bulb yield. Besides, the interaction effect of N rates and intra-row spacing had significant effect on fresh biomass yield, dry biomass yield, total bulb yield, harvest index and marketable bulb yield.

The partial budget analysis revealed that net benefit of Birr 232,486.00 ha^{-1} was recorded in the treatment which received 138kg N ha^{-1} at 7.5cm intra-row spacing followed by the same spacing supplied with 115kg N ha^{-1} and the control plot which give 213,587.00 and 102,164 Birr respectively. This indicated that the possibility of higher benefit of onion production with the application of 138kg N ha^{-1} at 7.5cm intra-row spacing in Site area. However, this combination cannot be generalized for all onion cultivars and locations in areas under Shebelle river basin at Gode district. Therefore, the experiment should be repeated over locations and seasons by including intra-row spacing narrower than 7.5cm as well as nitrogen rates higher than 138 kg ha^{-1}. This is because the yield did not plateau out up to the highest levels of nitrogen as well as at the narrowest plant spacing.

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