Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.6, No.21, 2016 www.iiste.org

Agronomic and Economic Evaluation of Nitrogen Fertilizer Rates and Intra Row Spacing on Growth and Bulb Yield of Onion (Allium cepa L.) under Rainfall Condition

Kiros Gebretsadik
Department of Plant Sciences, Aksum University, P.o.Box 314, Shire, Ethiopia

Nigussie Dechassa
Department of Plant Sciences, Haramaya University, P.o.Box 138, Dire-Dawa, Ethiopia

Abstract
A field experiment was conducted at Shire, Lemlem demonstration farm under rainfall condition to study the impact of nitrogen (N) fertilizer rates and intra row spacing on growth bulb yields and profitability of onion (Allium cepa L.). Treatments consisted of factorial combination of four rates of N fertilizer (0, 50, 100 and 150 kg ha^{-1}) and four intra row spacing (4, 6, 8, and 10 cm). The experiment was laid out as a Randomized Complete Block Design with three replications. The result of this study revealed that the interaction effect of N and spacing affected days to maturity and plant height. The main effect of N significantly affected most of the studied parameters while spacing affected number of leaves and yield. Days to maturity of onions were prolonged in response to the increased rate of nitrogen application. Increasing nitrogen from the nil to 150 kg N ha^{-1} decreased bolting percentage by 62%. Increasing the rate of nitrogen from 50 to 100 kg N ha^{-1} increased the total bulb yield and leaf number by about 26.7% and 29% respectively. However, increasing the rate of N further from 100 to 150 kg N ha^{-1} tended to decrease total bulb yield by 5.3 %. Higher marketable yield of 31.455 t ha^{-1} were obtained at 100 kg N ha^{-1}. The result of partial Budget analysis showed that 100 kg N ha^{-1} combined with 6 cm intra row spacing was found the best treatment than others in relation to bulb yield and economic benefits under the condition of Shire, northern Ethiopia.
Keywords: Nitrogen, Intra row spacing, Onion Bombay Red, Growth and Yield

1. Introduction

Onion (*Allium cepa* L.) is a vegetable crop grown for its pungent bulbs and flavourful leaves. It belongs to the genus *Allium* of the family *Amaryllidaceae* (Welbaum, 2015). Generally, all plant parts of alliums can be consumed by humans except perhaps the seeds (Rabinowitch and Currah, 2002). Onions have significant contributions to the nutritional requirements of human beings and have also medicinal values and are primarily consumed for their unique flavour or for their ability to enhance the flavour of other foods (Randle and Ketter, 1998).

Onions are probably cultivated in all countries of tropical Africa including Ethiopia (Grubben and Denton, 2004). Onion is important in the daily Ethiopian diet, cultivated both under rain fed and irrigated conditions. However, the national average yield is 10.75 t ha^{-1} (CSA, 2011) which is lower compared to other onion producing countries like the Republic of Korea (66.15 t ha^{-1}), USA (56.13 t ha^{-1}), the Netherlands (51.64 t ha^{-1}), Japan (46.64 t ha^{-1}) and Egypt (36.16 t ha^{-1}) in the production year of 2011 (FAO, 2012).

One of the major bottlenecks of onion production in Ethiopia is improper agronomic practices. Many reports indicate that, in Ethiopia the low productivity of vegetables including onions is attributed to depleting soil fertility, poor agronomic practices such as imbalanced fertilizer application (Lemma and Shimeles, 2003 and Fekadu and Dandena, 2006).

Ethiopian Institute of Agricultural Research (EIAR, 2004) recommended 100 kg DAP ha^{-1} and 150 kg urea ha^{-1} for onion production with no indication and consideration of appropriate spacing, cultivar, soil type and environmental conditions. The optimum level of any agronomic practices like plant population density and fertilizer rate varies with the environment and variety. To optimize onion productivity a full package of information is required for specific growing system (Gupta *et al*., 2000; Lemma and Shimeles, 2003). The use of optimum plant population density has a dual advantage. It avoids strong competition between plants for growth factors such as water, nutrients, and light. Conversely, it enables efficient use of available crop land without wastage (Zubelidia and Gases., 1977).

Spacing of 10 cm between two adjacent plants and 30 cm between rows was recommended when transplanting onions to permanent fields (FAO, 1995). However, this spacing is not optimum under all conditions of growth as well as crop or varietal characteristics. Varieties of onion may differ in root architecture, foliage and other growth characteristics. According to Jilani (2004), a cultivar performs differently under different agro climatic conditions and various cultivars of the same species grown even in the same environment often yield differently. The performance of a cultivar mainly depends on the interaction of genetic makeup and the environment. There is lack of improved techniques of onion production in northern Ethiopia particularly in the study area. This research is, therefore, initiated with the objective to determine the impact of nitrogen fertilizer and intra row spacing on growth and bulb yield of onion.

2. Materials and methods

2.1 site description

The experiment was conducted in 2014 from May to September under rainfall condition at **Shire, Lemlem demonstration farm**, Tigray State northern Ethiopia. It is located at an altitude of 1900 m above sea level (Finneran, 2005). The site is situated at latitude of 14°6′N and longitude of 38°17′E. The mean annual rainfall is 990 mm and average annual minimum and maximum temperatures are 12.4^o C and 28.5^o C, respectively. The rainy season extends from May to September and the maximum rain is received in the months of June to August. The field has sandy clay loam soil with pH of 6.57, organic carbon 1.29%, total nitrogen 0.08%, available phosphorus 43.62 parts per million, exchangeable potassium of 1.55 cmol (+) kg^{-1} and CEC of 14.93 cmol kg^{-1} soil (Table 1). The rural area around the study site is known for the mixed crop-livestock farming system (Yayneshet, 2010).

2.2 Experimental materials

Based on the agro-climatic requirements and yield potential onion (*Allium cepa* L.) cultivar Bombay Red was used for the experiment. Bombay Red is widely cultivated in the Study area using irrigation. The seeds were obtained from Melkassa Agricultural Research Centre. The variety was released by this research centre in 1998. The cultivar is adapted to altitudes ranging from 700 to 2000 m above sea level. It has flat globe-shaped medium size bulbs with light-red in color (EIAR, 2004). The sources of the fertilizers were urea (46% N) to supplying nitrogen for the experiment.

2.3 Treatments and design

The treatments consisted four levels of nitrogen fertilizer (0, 50, 100 and 150 kg ha^{-1}) and four intra row spacing (4, 6, 8, and 10 cm) with the same inter row spacing of 20 cm laid out as a randomized complete block design (RCBD) in a 4 x 4 factorial arrangements and replicated three times. The size of each plot was 1.20m x 2.40m accommodating ten single rows with 36, 24, 18 and 14 plants per row for the intra-row spacing of 4, 6, 8 and 10cm, respectively The inter-row spacing of 20cm was maintained for all plots and the distance between adjacent plots and blocks was 1m each.

2.4 Soil sampling

Pre-planting soil samples were taken randomly in a zigzag pattern from the entire experimental plots at the depth of 0-30 cm. Ten soil cores were taken by an auger from the whole experimental field and combined to a composited sample. The soil was broken in to small crumbs and thoroughly mixed. From this mixture, a sample weighing one kg was filled in to a plastic bag to analyse in triplicates. The composite sample was sub-divided into working samples for analysis.

The soil samples were analyzed, at Mekelle soil laboratory of Tigray regional laboratory, for pH at 1:2.5 soil-water ratio using a glass electrode attached to pH digital meter; organic matter was determined by using Walkley and Black (1934)method; total N was determined using Kjeldhal method as described by Dewis and Freitas (1975); available P was determined by the methods of Olsen and Dean (1965), exchangeable potassium and sodium were determined by potentiometer with 1M ammonium acetate at pH 7.0; CEC and texture was determined using standard procedures. The rating was done according to the suggestions of Hazelton and Murphy (2007) and Donald *et al*., (2011).

2.5. Data Collection

Data were collected on days to maturity, Plant height, bolting percentage, number of leaves per plant, bulb yield and Harvest index from plants in the eight central rows, leaving aside plants in the outer most rows as well as those at the end of each row, to avoid edge effects.

2.7. Statistical analysis

2.7.1. Data analysis

Data were subjected to analysis of variance (ANOVA) using SAS version 9.1 Statistical Software. Means that differed significantly were separated using the Least Significant Difference (LSD) test procedure at 5 % level of significance. Pearson Correlation coefficients were determined for parameters using the same software.

2.7.2 Economic Analysis

The economic analysis was computed using the procedure described by CIMMYT (1988) to identify economically attractive combination of nitrogen fertilizer and intra-row spacing. From the final experimental data of the average yield of 16 treatments was obtained. Then average yield was adjusted down wards by 10 % as field researchers have judged that farmers using the same technologies would obtain yields 10% lower than the yields obtained by researchers (CIMMYT, 1988). This was due to the fact that under experimental condition there was better crop management and small plot size. To obtain the gross field benefits it is essential to know the market price which is the value of one kg of onion bulb at harvest time. Adjusted yield multiplied by field price gives gross field benefit.

The cost and benefits were calculated for each treatment. Purchasing cost for Urea is taken as 11.5 Birr kg^{-1} and cost of daily labour is taken as 50 Birr day^{-1}. The selling price of onion Bombay red cultivar at the local market was 9 Birr. The variable cost of fertilizer and labour cost for application of fertilizer and transplanting seedlings for each treatment was reduced from gross benefit. Other costs that do not vary among all treatments (like ploughing, weeding, harvesting, etc) were not included as variable costs.

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

Adjusted yield (kg ha^{-1}): is the average yield which was adjusted downward by 10% to reflect the difference between the experimental and farmers' yield.

Total variable cost (Birr) = cost of fertilizer and labour cost for application of fertilizer and transplanting seedlings for each treatment

Gross field benefit = Adjusted yield x unit price of onion

Net benefit = Gross benefit – total variable cost

MRR analysis was carried out on undominated treatments in a stepwise manner and minimum marginal rate of return was take as 100%, as suggested by Farquharson (2006) and Shah *et al* (2009) especially for poor farmers in developing countries or for technologies requiring substantial change to a farming system.

$$\text{Marginal Rate of Return (MRR) (\%)} = \frac{\text{marginal increase in net benefit}}{\text{marginal increase in variable cost}} \times 100$$

3. **Results and discussion**

3.1. Soil Physico-Chemical Properties of the Study Site

The results of the analysis of the physico-chemical properties of the soil listed in Table 1 revealed that, the soil was sandy clay loam in texture (sand 67.20%, silt 11.30, and clay 21.50%). It has organic carbon content of 1.29%, total nitrogen content of 0.08%, available phosphorus content of 43.62 ppm, exchangeable potassium content of 1.55 cmol(+)Kg^{-1} , pH of 6.57 and EC (dSm^{-1}) of 14.93 and CEC of 14.93 cmol kg^{-1} soil (Table 1). Based on Hazelton and Murphy (2007) and Donald *et al*., (2011) rating, the **results of the soil analysis indicates that the experimental site was moderate in organic matter, very low in total nitrogen, very high in available phosphorus, high in exchangeable potassium, neutral in reaction and non saline soil**

Table 1. Soil Physico-chemical properties of the experimental site before planting

Soil property	Result	Type (Quality)
Soil particle size (%)		
Sand	67.20%	
silt and	11.30%	
clay	21.50%	
Textural class	Sandy clay loam	
pH	6.57	Neutral in reaction
Total N (%)	0.08	Very low or deficient
Organic Carbon (%)	1.29	Moderate
Organic matter %	2.23	**Moderate**
Exchangeable K (cmol (+)) kg^{-1}	1.55	High
Available P (ppm)	43.62	Very high
EC (dSm^{-1})	0.225	Non-saline
CEC (cmol kg^{-1} soil)	14.93	Moderate

Source: Mekelle Soil laboratory of Tigray Regional Soil Laboratory

3.2 *Days to maturity*

The interaction of nitrogen and intra-row spacing influenced days to maturity of onion plants (Table 2). Days to maturity were prolonged in response to the increased rate of nitrogen application. However, across the widening intra-row spacing from 4 to 10 cm, there was no consistent increase or decrease in days to maturity with the increase in nitrogen supply from 0 to 100 kg ha^{-1} (Table 2). But at 150 kg N ha^{-1}, widening, the intra-row spacing from 4 to 10 cm prolonged days to maturity significantly by about 12 days. Thus, plants with the most prolonged days to maturity (133 days) were recorded from the treatment supplied with 150 kg N ha^{-1} at the spacing of 10 cm. On the other hand, plants that reached physiological maturity earliest were obtained at 0 kg nitrogen ha^{-1}

combined with all intra-row spacing of 4, 6, 8, and 10 cm, which is within the range of 108 to 112 days. Therefore, plants grown at 150 kg N ha^{-1} at the intra-row spacing of 10 cm had duration in days to physiological maturity that was prolonged by about 20% than those grown at 0 kg N ha^{-1} at all intra-row spacing.

The result is consistent with the findings of Abdissa *et al*. (2011) who reported that nitrogen fertilization significantly extended days of physiological maturity by about 6 days over the unfertilized treatment. This may be due to the fact that N application extends the vegetative growth period of plants through its promotion of active vegetative growth, resulting in delayed maturity of plants (Marschner, 1995). This is also in agreement with the results of Brewester (1994) and Sørensen and Grevsen (2001) who reported that high rate of nitrogen promoted excessive vegetative growth and delayed maturity.

Table 2. The interaction effect of applied nitrogen and intra-row spacing on days to maturity

Days to Maturity					
N (Kgha^{-1})	Intra-row spacing (cm)				
	4	6	8	10	Mean
0	109.7gh	112.7fgh	108.7h	115.0efgh	111.50D
50	114.7efgh	116.3cdefg	115.3defgh	114.0fgh	115.083C
100	114.7efgh	121.3bdce	122.0bdc	123.3b	120.333B
150	121.3bdce	118.0bdcef	122.7cb	133.0a	123.750A
Mean	115.08B	117.08B	117.17B	121.33A	
LSD(0.05)	6.772				
CV (%)	3.451				

Means sharing a common letter are not significantly different at 5 % level of significance

3.3 Plant height

Intra-row spacing and nitrogen interacted to significantly influence plant height (Table 3). The mean values of the interaction effect of nitrogen and intra-row spacing on plant height at maturity showed that plant height increased with the increase in nitrogen level. However, across the widening of intra-row spacing from 4 to 10 cm, there was no consistent increase or decrease in plant height with the increase in nitrogen supply from 0 to 100 kg ha^{-1}. However, at 150 kg N ha^{-1} widening the intra-row spacing from 4 to 10 cm increased plant height significantly (70.733 to 80.26 cm). Thus, the tallest plants grew in the treatment supplied with 150 kg N ha^{-1} at the spacing of 10 cm (80.26 cm). On the other hand, the shortest plants were recorded at 0 kg nitrogen ha^{-1} combined with all intra-row spacing of 4, 6, 8, and 10 cm. Therefore, plants grown at 150 kg N ha^{-1} at the intra-row spacing of 10 cm were taller than those grown at 0 kg N ha^{-1} intra-row spacing averagely by about 74%.

Height of plants can be considered as one of the indices of plant vigour ordinarily and it depends upon vigour and growth habit of the plant. Denser planting may result in stiffer competition among plants for growth factors such as water, light, and mineral nutrients. Therefore, plant growth may be constrained of higher densities. Soil nutrients are also very important for the height of plants. So, higher dose of nitrogen increased plant height.

Table 3. The interaction effect of nitrogen and intra-row spacing on plant height at maturity

Plant height at maturity (cm)					
N (Kgha^{-1})	Intra-row spacing (cm)				
	4	6	8	10	Mean
0	47.25e	44.63e	44.51e	48.11e	46.13D
50	65.52cd	67.53cb	69.19cb	59.85d	65.52C
100	70.53cb	69.85cb	69.15cb	70.87cb	70.10B
150	70.73cb	73.34b	69.68cb	80.26a	73.50A
Mean	63.51A	63.84A	63.13A	64.77A	
LSD (0.05)	6.3237				
CV (%)	5.94				

Means sharing a common letter are not significantly different at 5 % level of significance

Accordingly, these results are in conformity with the findings of Sharma and Rastogi (1992) and Aliyu *et al*. (2008), who found that nitrogen, had significant effect on plant height of onion. The increase of plant height in response to the application of increasing nitrogen rates may be attributed to the increase availability of N in the soil for uptake by plant roots that may have enhanced vegetative growth through increasing cell division and elongation (Marschner, 1995, Halvin *et al*., 2003). This clearly showed that nitrogen mainly concerned with the vegetative growth of the plants. Similar findings were reported by Arboleya and Garcia (1993), Kumar *et al*. (1998), Khan *et al*. (2002), Mozumder *et al*. (2007), Aliyu *et al*. (2008) and Al-Fraihat (2009) where increased rate of nitrogen resulted in increase in plant height of onion. On the contrary, Abdissa *et al*. (2011) stated that application of 69 kg N ha^{-1} increased plant height by about 10% but further N application did not cause further significant change in plant height. This may be due to soil and agro-ecology difference of the experimental sites.

Table 4. The main effects of nitrogen and intra row spacing on plant height, bolting percentage leaf number, neck diameter, yield and harvest index and of onion

N (kg ha^{-1})	Plant height (cm)	Bolting (%)	Leaf number plant^{-1}	Neck diameter(cm)	Bulb Yield (t ha^{1})	Harvest Index (%)
0	46.127d	5.408a	7.833b	0.937b	18.31c	**73.033c**
50	65.523c	3.503b	6.667c	0.988b	25.93b	**74.535cb**
100	70.101b	2.290c	8.667a	1.046b	32.84a	**75.904ab**
150	73.503a	2.065c	8.333ab	1.210a	31.10a	**77.642a**
F-test	**	*	**	*	**	*
LSD(0.05)	3.16	0.639	0.783	0.115	2.156	**2.716**
Spacing (cm)						
4	63.511	3.305	6.583b	1.080	26.03b	**81.803a**
6	63.837	3.293	8.167a	1.055	28.32a	**76.205b**
8	63.135	3.340	8.167a	0.998	26.85ab	**72.979c**
10	64.771	3.328	8.583a	1.049	26.97ab	**70.128d**
F-test	Ns	Ns	**	Ns	*	**
LSD(0.05)			**0.783**		**2.156**	**2.716**
CV (%)	**5.94**	**23.115**	**11.925**	**13.204**	**9.563**	**4.327**

*Means sharing a common letter are not significantly different at 5 %level of significance Ns=non significant. *, ** significant at 5 % and 1 % respectively*

3.4. Bolting percentage

The analysis of variance showed that bolting percentage was highly significantly ($P < 0.01$) influenced by the main effect of nitrogen, but was not affected by the main effect of intra-row spacing as well as (Table 4).

Bolting percentage decreased with the increase in the rate of nitrogen application. In response to increasing the rate of nitrogen from 0 to 50 kg N ha^{-1} bolting percentage was decreased by 35%. When the rate of nitrogen increased further from 50 to 100 kg N ha^{-1}, bolting percentage again dropped by 35%. However, increasing the rate of nitrogen from 100 to 150 kg N ha^{-1} did not change bolting percentage (Table 4). In general, increasing nitrogen from the nil to 150 kg N ha^{-1} decreased bolting percentage by 62%.

This result is in line with that of Abdissa *et al*. (2011) who reported that nitrogen fertilization significantly reduced bolting in onion where the proportion of bolters per plot decreased by about 11 and 22% in response to application of nitrogen at 69 and 92 kg N ha^{-1}, respectively over the control treatment. This could be associated with the effect of N in extending the vegetative growth period of plants while delaying flowering. Yamasaki and Tanaka (2005) also found that low nitrogen promoted bolting in onion (*Allium fistulosum* L.) exposed to low temperature for 35 days. Bolting in bulb crop is triggered in response to exposure to conditions such as sufficiently low temperature or limited N supply which induce flowers to emerge before bulbs are adequately developed to suppress flower initiation (Roberts *et al*., 1997).

The carbon-to- nitrogen (C/N) ratio determines whether the onion plant remain vegetative or process a flower stalk (Rabinowitch, 1990). Díaz-pérez *et al*. (2003) found that bulb N content increased with N fertilization rate and that bolting decreased seedily with increasing bulb and shoot N contents. This indicates that increasing N fertilization rates possibly decreased onion plant's C/N ratio which could partly explain results in this study. Although this study did not show significant difference in bolting percentage due to intra row spacing, some research results revealed significant differences among plants grown at different intra-row spacing in bolting percentage. Mohamed (1991) reported that closer spacing of 5 x 20 cm increased percentage of bolters by 14.5%, while nitrogen application decreased the incidence of bolting. Similarly, high competition among plants in densely populations was indicated to result in smaller bulbs that are less susceptible to bolting (Nourai, 1988).

3.5 Number of leaves per plant

The analysis of variance showed that the main effects of nitrogen rate and intra-row spacing highly significantly ($P < 0.01$) influenced the number of leaves per plant (Table 4).

Increasing the rate of nitrogen from 0 to 50 kg N ha^{-1} significantly decreased leaf number. However, increasing the rate of the nutrient further from 50 to 100 kg N ha^{-1} increased leaf number significantly by about 29%. Increasing the rate of nitrogen beyond this level did not affect the number of leaves produced by the onion plant (Table 4).

The decrease in the number of leaves with the increase of nitrogen rate from nil to 50 kg N ha^{-1} was inexplicable, but could be attributed to human error or other factors. However, increase in the number of leaves with further increase in the rate of nitrogen could be attributed to enhanced photo-assimilate production and cell division, and vegetative growth in response to the enhanced sappy of the nutrient as suggested by Marschner

(1995). This shows that, nitrogen played an important role in leaf production and vigorous vegetative growth.

Similar results were reported by Nasreen *et al*. (2007) who found that application of 120 kg N ha^{-1} significantly increased the number of leaves per plant. The positive effect of nitrogen in increasing the number of leaves of onion was confirmed by Vachhani and Patel (1993), Kumar *et al*. (1998) and Khan *et al*. (2002) who observed that the number of leaves per plant increased with increasing nitrogen levels up to 150 kg ha^{-1}.

The analysis of variance also revealed that widening the intra-row spacing from 4 to 6 cm significantly increased the leaf number of onions. However, widening the spacing beyond 6 cm did not lead to significant differences in leaf number produced per plant. The leaf number obtained in response to spacing the plants 6 cm part exceeded the leaf number of plants spaced 4 cm apart by 24% (Table 4). This increase in the number of leaves with widening of plant spacing may be attributed to ease of competition among plants for growth resources.

Corroborating the result of this study, Singh and Sachan (1999) reported for onion that the greatest number of leaves per plant was found in the widest row spacing. This could be partly due to the fact that wider spaced plants produce more auxiliary branching than plants spaced at closer spacing, which may have resulted in higher leaf number per plant. This result is, however, incongruent with the findings of Akoun (2004) who reported on onion crop that more leaves were produced at lower planting density and lower leaf number at the higher planting density.

3.6 Total bulb yield

The maximum bulb yield was recorded at 100 kg N ha^{-1} (32.84 t ha^{-1}). Increasing the rate of N from 0 to 50 kg N ha^{-1} markedly increased total bulb yield by about 41.6 % (Table 4). Increasing the rate of nitrogen from 50 to 100 kg N ha^{-1} increased the total bulb yield further by 26.7 %. However, increasing the rate of N from 100 to 150 kg N ha^{-1} tended to decrease total bulb yield by 5.3 %. Increasing the rate of N from nil to 100 kg N ha^{-1} significantly increased total bulb yield by 79.4 %. Therefore; further addition of nitrogen doses above 100 kg ha^{-1} did not increase yield of the onion crop in the study area.

Several researchers reported similar results. Aliyu *et al*. (2008) found that increase in N dose up to 100 kg N ha^{-1} resulted in increased yield of onion bulbs but further increase of nitrogen to 150 kg N ha^{-1} did not significantly increase the yield . Khan *et al.* (2002) also reported that maximum yield of onion bulbs was obtained from application of mineral N fertilizer at the rate of 100 kg N ha^{-1}. Similarly, Brewester (1994) reported that yield incensement in the range of 0 to 150 kg ha^{-1} after which it decreased.

Increasing the intra row spacing from 4 to 6 cm significantly increased the total bulb yield by 8.8% (Table 4). However, increasing the intra row spacing to all higher spacing did not change total bulb yield. This result shows that plants grown at intra row spacing of 6 cm produced the higher mean total bulb yields (28.32 t ha^{-1}). Mohamed (1991) also reported that, closer intra row spacing of 5 cm increased bulb yield by 7.6% over 10 cm. Similarly, Geremew *et al*. (2009) also found that in Bombay Red at the intra row spacing of 4 cm produced the highest yield compared with 10 cm intra row spacing at the rift valley of Ethiopia. However, Viloria *et al*. (2003) found optimum yield at 10 cm x 20 cm spacing after compared with 12 × 20 cm and 6 × 20 cm. Such difference may be difference in soil condition, variety of onion used or agro ecological variability.

3.7 Harvest index

Harvest index increased with the increase in the rate of nitrogen application. The highest harvest index, (77.642 %), was produced at the application of 150 kg N ha^{-1}, which increased the parameter by about 6 % compared with the control (Table 4). This indicates that application of higher amounts of N is important for onion to produce more assimilates for growth, development, and bulb production. Similarly, Abdissa *et al*. (2011) indicated that N application improved harvest index in onion by increasing both bulb dry weight and total biomass yield.

Increasing the intra row spacing of onion, linearly and significantly decreased harvest index (Table 4). Widening the intra row spacing from 4 to 6, 8, and 10 cm significantly reduced harvest index by 7, 4, and 4%, respectively in the order mentioned here. The harvest index of plants grown at the narrowest intra row spacing of 4 cm exceeded the harvest index of plants grown at the widest intra row spacing of 10 cm by 14 %. This result demonstrates that bulbs of plants grown at the narrowest spacing were compact and had more dry matter relative to the smaller biomass produced due to stiffer competition between plants. On the other hand, bulbs produced by plants grown at the widest spacing produced higher bulb dry biomass yield but also that of above ground dry biomass yield due to relatively sufficient growth factors for photo-assimilation, thereby reducing the relative ratio of bulb dry matter to the dry matter of total biomass, which is harvest index.

3.8 Cost benefit analysis

Table 5 displays partial budget analysis. The cost benefit analysis revealed that, the highest net benefit, Birr 266028 was obtained by application of 100 N kg ha^{-1} at intra row spacing of 6 cm followed by the net benefit of

Birr 256206, which was obtained using 100 N kg ha^{-1} at intra row spacing of 10 cm. The lowest net benefit, Birr 128394, was obtained from the check which is nil N with 10 cm intra row spacing. When the new technology suppressed the conventional practice, it is said to be Undominated. It becomes unnecessary when the new technology costs less than the farmers' present practice. When the new technology yield lower benefit then the technology is indicated as dominated. 9 of the 16 treatments were dominated.

Table 6 shows the marginal analysis. Dominated treatments were off the comparison for marginal analysis. Calculation of net benefit accounts for costs that vary but also it is important to compare the extra or marginal costs with the extra or marginal net benefits. The procedure of calculating the marginal rates return (MRR) of alternative treatments, proceeding in step wise from the least costly treatment to the next most costly treatment and deciding if they are acceptable to farmers is called marginal analysis (CIMMYT, 1988).

Table 5 Partial budget analysis

Treatments		Average yield	Adjusted yield	Gross field benefit (Birr	Total variable	Net Benefit	Dominance
N (kg ha^{-1})	Spacing (cm)	(t ha^{-1})	(t ha^{-1})	ha^{-1})	cost (Birr)	(Birr)	
0	10	15.88	14.292	128628	234	128394	Undominated
	8	15.98	14.382	129438	305	129133	Undominated
	6	15.97	14.373	129357	375	128982	Dominated
	4	18.52	16.668	150012	429	149583	Undominated
50	10	24.42	21.978	197802	1573	196229	Undominated
	8	24.16	21.744	195696	1644	194052	Dominated
	6	26.50	23.85	214650	1714	212936	Undominated
	4	21.38	19.242	173178	1768	171410	Dominated
100	10	31.99	28.791	259119	2913	256206	Undominated
	8	31.86	28.674	258066	2984	255082	Dominated
	6	33.22	29.898	269082	3054	266028	Undominated
	4	28.75	25.875	232875	3108	229767	Dominated
150	10	29.53	26.577	239193	4252	234941	Dominated
	8	29.71	26.739	240651	4323	236328	Dominated
	6	31.18	28.062	252558	4393	248165	Dominated
	4	28.26	25.434	228906	4447	224459	Dominated

Table 6. Analysis of marginal rate of return

Treatments		adjusted yield (tha^{-1})	Net Benefit (Birr)	Total Variable Cost (Birr)	Marginal increase net benefit (Birr)	Marginal increase variable Cost (Birr)	MRR %
N (kg ha^{-1})	Spacing (cm)						
0	10	14.292	128394	234	739	71	1040.9
0	8	14.382	129133	305	20450	124	16491.9
0	4	18.52	149583	429	46646	1144	4077.5
50	10	24.42	196229	1573	16707	141	11848.9
50	6	26.50	212936	1714	43270	1199	3608.9
100	10	31.99	256206	2913	9822	141	6966.0
100	6	33.22	266028	3054			

MRR is calculated by dividing the marginal increase in net benefit with the marginal increase in variable cost and multiplied by 100.

Based on Analysis of marginal rate of return, all of the results showed more than the minimum rate of return (100%). Further comparison will be made depending on the MMR% and net benefit between the treatments. Recommendations are not necessarily based on the highest marginal rate of return. For farmers who use onion using intra-row spacing of 8 cm and nil nitrogen fertilizer gives highest rate of return (16491.9%), but if farmers stopped there, they would miss the opportunity of further earnings, at attractive rate of returns, by investing 100 kg of nitrogen fertilizer and reducing intra row spacing from 8 cm to 6 cm. Farmers will continue investing as long as the returns to each extra unit invested (measured by the marginal rate of return) are higher than the cost of extra unit invested (measured by the minimum acceptable rate of return) (CIMMYT, 1988).

MRR implies what a producer can get to receive by switching technologies from the farmers practice to the improved new one, hence, 6966% MRR indicates by investing 1 Birr a farmer can get 69.66 Birr recorded from treatment combination of 100 N kgha^{-1} and 6 cm intra row spacing which is above the minimum rate of return and produced the highest net benefit. High bulb yield (33.22 t ha^{-1}) was obtained at this treatment. High net benefit from the foregoing treatments could be attributed to high yield and the low net benefit was attributed to low yield.

Thus, 100 N ha^{-1} combined with 6cm intra-row spacing could be recommended and 10cm combined with 100kg N ha^{-1} and 100kg N ha^{-1} combined with 10cm as second and third alternatives. High bulb yield and low cost evidently leads to maximum income. Therefore, it is advisable to apply 100 kg nitrogen with intra-row spacing of 6 cm to get high profit in the in onion production under rain-fed condition in the study area.

Conclusion

Although onion is commonly produced using irrigation, it is possible to produce under rainfall condition to maintain higher yield and economic benefit. Using optimum N fertilizer rate and intra row spacing helps optimum marketable bulb size. From the results of this investigation, it can be concluded that, nitrogen application at the rate of 100 kg N ha^{-1} combined with intra row spacing of 6 cm and inter tow spacing of 20 cm is optimum to earn maximum marketable yield and higher economic profit from Onion production planted during the rainy season in areas like Shire area, northern Ethiopia.

Acknowledgement

The authors express great gratitude to the Well Foundation Organization in Shire-Indaselassie for allowing their farm and facility. This work was supported by Aksum University.

References

Abdissa Y., Tekalign, T. and Pant, L.M. (2011). Growth, bulb yield and quality of Onion (Allium cepa L.) as influenced by nitrogen and phosphorus fertilization on vertisol I. growth attributes biomass production and bulb yield. *African Journal of Agricultural Research Vol. 6(14), pp. 3252-3258*. http://www.academicjournals.org/AJAR. [accessed 08.07.15]

Akoun, J. (2004). Effect of Plant density and manure on the yield and yield components of common onion (Allium cepa L.) Var. Nsukka Red. *Nigerian Journal of Horticultural Science. Vol.*9: 43-48.

Al-Fraihat, H.Ahmad. (2009). Effect of different nitrogen and Sulphur levels on growth, yield and quality of onion (*Allium cepa* L.). *Jordan Journal of Agricultural Science* 5(2):155-165.

Aliyu, U., M.D. Magaji, A. Singh and S.G. Mohammed. (2007). Growth and Yield of Onion (*Allium cepa* L.) as Influenced by Nitrogen and Phosphorus Levels. *International Journal of Agricultural Research, 2: 937-944.*DOI: 10.3923/ijar.2007.937.944.URL**:** http://scialert.net /abstract/?doi=ijar.2007.937.944.

Arboleya, J. and Garcia, C. 1993. Adjustment of fertilization in relation to different planting densities, With or Without Irrigation Mendoza Argentina. http://scialert.net/fulltext/? doi=jps.2008.188.193&org.

Brewester, J.L. (1994). Onions and other vegetable *Alliums*. CAB International. Wallingford. UK. p. 236.

CIMMYT. (1988). From agronomic data to farmer recommendations: an economics training manual (completely revised edition). CIMMYT, Mexico, DF, pp 9-38.

CSA, (Central Statistics Authority). (2011). Agriculture sample survey. September to December 2010. Report on Area and production of major Crops (Private peasant holdings, meher season). Bulletin. Vol. I. Addis Ababa, Ethiopia. http://www.csa.gov.et [accessed April 4, 2014].

Dewis J, Freitas P. (1975). Physical and chemical methods of soil and tissue analysis. FAO Bulletin No. 10. Rome. pp. 275.

Díaz-pérez, J. C., Purvis, A. C., & Paulk, J. T. (2003). Bolting , Yield , and Bulb Decay of Sweet Onion as Affected by Nitrogen Fertilization. *J. AMER. SOC. HORT. SC*, *128*(1), 144–149.

Donald A, Dan M, Jim S, John M (2011). *Soil testing interpretation guide*. Oregon State University, U.S.A.

EIAR, (Ethiopian Institute of Agricultural Research). (2004). Directory of released crop Varieties and their recommended cultural practices. Addis Ababa, Ethiopia.

FAO. (1995). STAT Data. Production yearbook. Rome.

FAO. (2012). STAT Data. http;//www.fao.org. [accessed December 11, 2014].

Farquharson R. (2006): Production response and input demand in decision making: nitrogen fertilizer and wheat growers. Australasian Agribusiness Review - Vol.14 – 2006 Paper #5.

Fekadu M., and Dandena, G. (2006). Review of the status of vegetable crops production and marketing in Ethiopia. Uganda Journal of Agricultural Sciences 12(2): 26-30.

Finneran Niall. (2005). The Archeological Landscape of the Shire Region, Western Tigray, Ethiopia. In: Annales d'Ethiopie. Volume 21, année pp. 7-29; doi: 10.3406/ethio.2005.1091http://www.persee.fr/doc/ethio_0066-2127_2005_num_21_1_1091

Geremew A., Teshome, A., Kasaye, T. and Amenti, C. (2009). Effect of intra-row spacing on yield of three onion *(Allium cepa l.)* Varieties at Adami Tulu Agricultural Research center (mid rift valley of Ethiopia). *Journal of Horticulture and Forestry*. Vol. 2(1) pp. 007-011. http://www.academicjournals.org/jhfJanuary. (accessed 22.01.15).

Grubben, G. J. H. & Denton, O. A. (eds). (2004). Plant resources of Tropical Africa 2. Nordic Journal of Botany, 23: 298. doi:10.1111/j.1756-1051.2003.tb00397.x

Gupta, R.P., Sharma, V.P. (2000). Effect of different spacings and levels of nitrogen for production of export quality onion bulbs planted on raised bed. *News Letter National Horticultural Research and Development Foundation* India 20:13–16

Halvin, J.L., James, D.B., Samuel, L.T. and Warner, L.N. (2003). Soil fertility and fertilizers an introduction to nutrient management.6th ed. Peason education Inc. New Delhi, India.

Hazelton, P. and Murphy, B. (2007). Interpreting soil test results. What do all the numbers mean? CSIRO Publishing, Victoria.

Jilani, M. S. 2004. *Studies* on the management strategies for bulb and Seed production of different cultivars of onion *(Allium cepa L.)*. a dissertation submitted to NWFP Agriculture University, Peshawar, Pakistan.

Khan, H.M. Igbal, Ghaffoor, A. and Wasseem, K. (2002). Effect of various plant spacing and different levels of nitrogen on the growth and yield of onion (Allium cepa L). Journal of Biological Science. 2;545-547

Kumar, H.J., Singh, V., Ajay, K., Mahak, S, Kumar, A. and Singh, M. (1998). Studies on the influence of nitrogen on growth and yield of onion CV. Patna Red. *Indian Journal of.Agriculture Research*. 32:88-92.

Lemma Dessalegn and Shimeles Aklilu. (2003). Research Experiences in Onion production. Research Report No. 55. Ethiopia Agricultural Research Organization. Addis Ababa.

Marschner, H. (1995) Mineral Nutrition and Yield Response. Mineral Nutrition of Higher Plants, (2nd edn), Academic press. London, UK, pp. 184-200.

Mohamed, E.N.O.M. (1991). Effect of plant population and nutrition on yield and quality of onion in Kassala, Sudan. http://arcsudan.sd/arc/conferences/meeting37/pdf/5.pdf

Mozumder, S.N. Moniruzzamanad, M., and Halim, G.M.A. (2007). Effect of Nitrogen, Potassium and on the yield and storability of transplanted onion (*Allium cepa* L.) in the hiily region. *Journal of Agricultural and Rural development*. 5(1 and 2),58-62.

Nasreen, S, Haque, M.M., Hossain, MA. and Farid ATM. (2007). Nutrient uptake and yield of onion as influenced by nitrogen and sulphur fertilization*. Bangladesh J. Agric. Res.*. 32(3): 413-420.

Olsen SR, Dean, LA. (1965). Phosphorus. In: Methods of Soil Analysis. American Society of Agronomy. Madison, Wisconsin, 9: 920 – 926.

Rabinowitch H.D. and Currah L. (eds.). (2002). Allium Crop Science: Recent advances. CABI Publishing. Wallingford, UK. 515 pp

Rabinowitch, H.D. (1990). Physiology of flowering. In: Rabinowitch, H.D. and Brewster, J.L. (eds).*Onions and Allied Crops*, Vol. I. *Botany, Physiology, and Genetics*. CRC Press, Boca Raton, Florida, pp. 113–134.

Randle W.M. and Ketter C.A. (1998). Pungency assessment in onions. Proceedings of the19 workshop conference of the Association for Biology Laboratory Education (ABLE). pp177-196. http://www.zoo.utoronto.ca/able/volumes/copyright.htm. [accessed April 14, 2014].

Roberts, E.H., R.J. Summer field, R.H. Ellis, P.Q. Craufurd, and T.R.Wheeler. (1997). The induction of flowering, p.69-99. In: H.C. Wien (ed). The physiology of vegetable crops. CAB Intl. Ithaca. N.Y

Shah H, Sharif M, Majid A, Hayat U and Munawar A. (2009). From experimental data to farmer recommendation: An economic analysis of on farm trial of UMMB feed for milking animals in rain-fed Pothwar, Pakistan. Livestock Research for Rural Development. http://www.lrrd.org. [accessed April 4, 2014].

Sharma, S.K. and Rastogi, K.B. (1992). Effect of nitorgen nutrient and spacing on seed production of cutflowers. *Indian Journal of Horticulture.* 49: 274–6.

Singh, S.R. and Sachan, B.P. (1999). Interaction of bulb size and spacing on seed yield and yield attributing trait of onion (Allium cepa L.) *Scientific Horticulture*. 6: 126-128

Sørensen, J. N. and Grevsen, K. (2001). Sprouting in bulb onions (*Allium cepa* L.) as influenced by nitrogen and water stress. *Journal of Hort. Sci. Biotech*., 76: 501-506.

Vachhani, M.U. ans Patel, Z.G. (1993). Growth and yield of onion (*Allium cepa*, L.) as influenced by levels of nitrogen, phosphorus and potash under South Gujarat conditions. *Progressive Hort*.. 25(3): 166-167.

Viloria A., Arteaga L., Díaz L. and Delgado D., 2003. Effect of N-P-K fertilization and planting distance on onion (Allium cepa L.) yield. *Bioagro.* 15:129–133.

Walkley A, Black, CA. (1934). Determination of organic matter in the soil by chromic acid digesion. *Soil Sci*., 63: 251-264.

Welbaum, G.E. (2015).Vegetable Production and Practices. Virginia Tech University, USA http://www.cabi.org/bookshop/book/9781845938024. 486pp. (accessed 12.02. 2016).

Yamasaki, A. and Tanaka, K. 2005. Effect of nitrogen on bolting of bunching onion (*Allium fistulosum* L). *Hort. Res. (Japan)*. 4(1): 51-54.

Yayneshet, T. (2010). Feed resources available in Tigray region, northern Ethiopia for production of export quality meat and Livestock. Addis Ababa. www.igad-data.org/livestock-production/doc/feed-resources-assessment-in-tigray-regional-state-ethiopia.

Zubelidia, A. and Gases, J.L. (1977). Effect of spacing and Number of stem on the Earliness and Total yield of Tomato cultivars. *Product. Veg*. 7: 73.