Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.6, No.15, 2016

Yield and Yield Components of Leek (Allium ampeloprasum var. porrum L) as Influenced by Levels of Nitrogen Fertilizer and Population Density at Areka, Southern Ethiopia

Birhanu Lencha Kiffo Major Advisor:Dr Kebede W/Tsadik Co-advisor Dr. Tamado Tana
Haramaya University Department of Plant Science, School of Graduate Studies
Haramaya University (Hu)
M.Sc. Thesis

Abstract
A field experiment was conducted to determine the effects of intra-row spacing and nitrogen fertilizer rates on yield, yield components and bulb quality of leek at Areka Agricultural Research Centre, Woliata Zone. Treatments comprised of five nitrogen levels (0, 69, 92,115 and 138 kg ha^{-1}) and three intra row spacing levels (5 cm, 10 cm and 15 cm)which were laid out in factorial arrangement in randomized complete block design with three replications. Carentan Giant leek variety was used for the experiment. Data were collected on plant height, leaf number, leaf length, pseudo-stem length shaft diameter fresh weight dry matter content, marketable and unmarketable and total yield(t/ha) The result revealed that the main effects of nitrogen rates and intra row spacing had significant effects on non marketable pseudo-stem, total yield, total marketable pseudo-stem number and fresh weight. There was no statistical difference ($p<0.05$) on plant height, leaf number, leaf length leaf width, shaft diameter dry matter content due to treatments. The result showed that interaction of nitrogen rates and intra row spacings was not significantly ($p<0.01$) influenced in all parameters. Specifically, both marketable and total yields showed increasing trend with increase in nitrogen rates where the highest total marketable yield (46.68 t ha^{-1}) and total yield (48.63 t ha^{-1}) were recorded at the rate of 138 kg N ha^{-1}and intra row spacing5cm which was 39.16(t/ha) obtained Regarding the N fertilization, extended days to physiological maturity was recorded with nitrogen application rate up to 115 kg N ha^{-1}. The results of the experiment suggested that the leek variety carentan giant responded well to the application of nitrogen fertilizer rates .In conclusion, application of 138 kg N ha^{-1} nitrogen and intra row spacing of 5 cm was found to be promising for yield of leek.

1. INTRODUCTION

The leek (*Allium ampeloprasum* var. *porrum* L.) belongs to the genus *Allium* of the family *Alliaceae* (Hanelt, 1990). It is closely related to the onions. It is a biennial plant and its reproductive system is predominantly cross-fertilization although self fertilization is possible (Meer and Hanely, 1990). Leek is a slow growing monocotyledonous species of the genus; it is characterized by broad, flat, tightly wrapped, dark green leaves, a long, thick white stalk, and a slightly (to some extent) bulbous end. It is very tolerant to cold weather, although the optimum temperature for vegetative growth is around 20 °C. The leaves and long white blanched stem are eaten cooked or can be added to salads (Theunissen and Schelling, 1998).

Leek is one of the most important bulbous crops cultivated commercially in nearly most parts of the world (Simon, 1992). It contributes significantly to nutritional value of the human diet and is primarily consumed for its unique flavor or for its ability to enhance the flavor of other foods (Randle and Ketter, 1998). Its distinctive pungency is due to the presence of a volatile oil (allylpropyl disulphide). The mature bulb contains some starch, appreciable quantities of sugars, some protein, and vitamins A, B, and C (Decoteau, 2000). It is also used as preservative and medicine (Vohra *et al.,* 1994).

On the basis of production volume averaged over the years 2002–2004, world production in millions of tonnes were 54.2 for dry bulb onions, 13.4 for garlic and 4.4 for green onions plus shallots and, averaged for the years 2003–2005, 1.78 for leeks and others (FAO, 2007). It is grown in more than 130 countries with total world production estimated at 599, million tons, covering about 10.9 million hectares (FAOSTAT, 2010). Based on the average production from 2008-2010, the world's top producer of *Alliums,* including onion, shallot, garlic and leek, is China, contributing an average of 31% to the total production followed by India (10%). Tropical countries, having about 45% of the world's arable land, grow about 35% of the worlds *Alliums* (Mohamed, 2010).

In Ethiopia, the *Alliums* group are among the most important bulb crops produced by small farmers and commercial growers both for local uses as well as for export (Metasebia and Shimelis, 1998; Getachew and Asefaw, 2000). Metasebia and Shimelis (1998) reported that the per capita consumption of these crops is about 1.74 kg and 5.9 kg in rural and urban areas, respectively. Leeks are spread throughout the country, being cultivated under both irrigated as well as rain fed conditions in different agro- climatic regions. The best growing altitude for leeks under Ethiopian condition is between 700 and 1800 m a.s.l (Lemma and Herath, 1992; Aklilu, 1997). Statistics on the production of *Alliums* in Ethiopia showed that about 32,786.30 ha of land is cultivated and 0.89 million tons of bulbs produced (CSA, 2008).). However, currently, there is no information about the area and the status of leek production in Ethiopia (FAOSTAT, 2010; CSA, 2008. Among the *Allium* crops, onion and leek, though of a recent introduction, are rapidly becoming popular vegetables among consumers (Lemma and Shimeles, 2003). However, the average yield of leek is about 5 t ha^{-1}, which is very low compared to the world's average production of 16 t ha^{-1}. Many diverse and complex abiotic, biotic and human factors are believed to have contributed to the existing low productivity of *Allium*, including leek, in Ethiopia (Lemma and Shimeles, 2003).

The commercial product of leek is its pseudo-stem and leek's pseudo-stem yield varies depending on cultivar, sowing date and planting density (Mondal, 1985). The author further indicated that bulb yield increases with plant density and that this positively correlates with the percentage light interception by the crop leaf canopy. In addition, Brewster (1994) reported that leek bulb yield increased asymptotically as plant density increases and that mean bulb size correspondingly declined.

According to Larkcom (1991), the recommended spacing for improved Leek (*Allium ampeloprasum var.porrum)* production in China and Japan is 10 x 15 x 40 cm spacing, where 10 cm is the spacing between plants, 15 cm is the spacing between rows on a bed and 40 cm is the width of plant bed including water path used for irrigating the plant. But this recommendation is irrespective of the *Allium* species and varieties cultivated and only for furrow irrigation system. There is insufficient information on appropriate plant spacing for rain fed method of leek production. Farmers in the different parts of the country are often observed to use higher or lower densities than the general spacing recommendation for *Allium*.

In areas around Areka Agricultural Research Centre, production of leeks, as a rain fed crop, is commonly practised with single row method of planting. In the area, leek is produced for home consumption and for local market as a source of cash. Seedlings are raised from seeds and transplanted at variable spacings, wider or closer than that stated by Lemma (2004). In general, farmers are not aware of the different agronomic practices influencing yield; planting leek at appropriate density is no exception. Thus, optimum planting density for leek is not known in the intended study area.

Leeks are more susceptible than most crop plants in extracting nutrients because of their shallow and un-branched root system; hence, they require and often respond well to additional fertilizers (Brewster, 1994). Nitrogen, phosphorus and potassium are often referred to as the primary macronutrients because of the general probability of plants being deficient in these nutrients and because of the large quantities taken up from the soil relative to other essential nutrients Marschner, (1995). Leeks require about 200-250 kg N ha^{-1} (Sulistiorini and Meer 1993). On sandy loam soil in a semi arid region in the central Rift Valley of Ethiopia, *Allium* species are indicated to benefit from application of 90 to 120 kg N ha^{-1} for optimum production of leek (Aklilu, 1997).

Considering the importance of leek as one of the potential vegetable crops for both domestic consumption and export, it is very important to increase its productivity along with appropriate management practices. Therefore, there is a need to identify appropriate spacing and nitrogen. The present study is, therefore, proposed with the following objective.

- ✓ To determine the effect of intra-row spacing and nitrogen fertilizer rate on yield, yield components and quality of leek.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The experiment was conducted at Areka Agricultural Research Centre, Woliata Zone Southern Nations Nationalities and Peoples Regional State during the cropping season of 2012. The experiment site is located 300 km south west of Addis Ababa and 259 km south west of Awassa. The geographical location of the study area is 37^{o} 40' 13.6" E longitude, 7^{o} 11' 30.5"N latitude, situated at an altitude of 1734 metres above sea level. The area has an average annual rainfall ranged from 900-1400 mm, and average minimum and maximum temperatures of 14.9 and 22.9 ^{o}C, respectively (BOARD, 2008 and Dawit, 2010).

Generally, the study area soil is characterized with sub angular structure at the surface layer (0 to 30 cm) while the sub surface soil layers has strongly developed angular blocky structure with the good porosity. The soil is silt-loam in texture and moderately deep (50 cm). Since bulk density values are less than 1.4 g/cm^3, the soil is not very compact to limit root development. The soil reaction is slightly acidic with pH values ranging from 4.7 to 5.06. The organic matter ranges from 2.0 to 3.4% at surface soils which is medium to high. In the sub-surface horizons its content decreases to about 0.3 to 0.8% which is low. The total nitrogen content of the top-soil is medium to high and its content ranges from 0.15 to 0.62%.The available phosphorus content in the surface soils is 16.02 mg kg^{-1} (Appendix Table 1).

2.2 Meteorological data of study area

Climatic data was measured in a meteorological station located in the experimental field, about 6 km distance from the experimental plots. The duration of growth period was from June to September 2012. Appendix table 2 presents the monthly average air temperature and rainfall from June to September for the years 2005 to 2013. The weather conditions during the growth period varied slightly from the 5 yeas average. The growing season was relatively hotter than the 5-year average. Average monthly temperature in the summer period of 1st June to 30th August was above normal. A significant drop in temperature was observed in September, especially in the third week of this month. The total precipitation during the vegetation period of the crop was relatively lower than in the 5-year average. Rainfall shortages occurred especially in August (10.5 mm). However, crop growth was not affected because supplemental irrigation was given as needed.

2.3. Plant Material
Leek variety, namely Carentan Giant was used as experimental material. It is introduced from France and is popular in eastern Ethiopia, particularly in Hararghe. The source of the seed was from Addis Ababa market. This variety is characterized by early maturation, short thick shaft plant and is well adapted to tropical highlands for better yield.

2.4. Treatments and Experimental Design
The treatments consisted of 3x5 factorial combinations of plant populations (5, 10, and 15 cm intra-row) in rows of 40 cm apart, giving population densities of 500,000, 250,000and 166,667 plants ha^{-1}, respectively and five levels of nitrogen (0, 69, 92, 115, 138 kg N ha^{-1}). The treatments were laid out in factorial arrangement in randomized complete block design with three replications. The treatments were randomly assigned to each plot. The size of each plot was 2.4 m long and 2 m wide and the net plot size was (2.44 m^2). Individual plots and the blocks were separated by space of 0.8 m and 1.2 m, respectively.

2.5. Planting and Cultural Practices
The field was ploughed 3 times before planting. Seeds of Carentan Giant were sown on seedbed of 1m x 10 m for raising seedlings in the first week of August 2012. The seedlings were managed in the nursery as per the practices of Areka Agricultural Research Center until seedlings reached a stage of transplanting.

2.5.2 Soil sampling and analysis
Pre-planting soil samples were taken randomly in a zigzag fashion from the experimental plots at the depth of 0-30 cm. Ten soil cores were taken using an auger from the whole experimental field and combined to form a composite sample in a bucket. The soil was broken to in small crumbs and thoroughly mixed. From this mixture, a sample weighing one kg was filled to in a plastic bag. This was replicated two times and prepared for the analysis.

The soil was air dried and sieved through a 2 mm sieve. Then, soil pH was determined by diluting the soil in a 0.01 M $CaCl_2$ solution in the ratio of 1 soil volume to 2.5 volume of the $CaCl_2$ solution. Thus, twenty-five ml of the 0.01M $CaCl_2$ solution was added into soil sub samples each weighing 10 g. After equilibrating for 2-3 hours, the suspensions was filtered and the pH measured by a glass electrode. Texture of the soil was determined by sedimentation method (Hesse, 1971).

The soil samples were analyzed for total nitrogen and available phosphorous and organic carbon. Total nitrogen of the soil was determined by the micro Kjeldhal procedure. Organic carbon was determined by the method of Nelsen and Sommers (1982). Available phosphorous content of the soil was determined by extraction with 0.5M $NaHCO_3$ (Olsen *et al*., 1954). Phosphorus in the extracts was determined with atomic absorption spectrophotomer calorimetrically according to the molybdenum blue colour method of Murphy and Riley (1962).

3. RESULTS AND DISCUSSION
3.1. Plant Growth Parameters
3.1.1. Plant height
The main effects of nitrogen rates and intra row spacing as well as the interaction effects of the factors were non-significant on height of leek plant (Appendix Table 3). However, it was observed that treatments did not have statistically difference among the means. There might be insufficient nutrient distribution to various plant parts, and high soil temperature affected the plant part that made undesirable elongation. In addition to this, the soil status was slightly acidic and light intensity affected both morphological and physiological of the leek plant.

Generally, the plants did not attain their respective height because of insufficient mineral nitrogen in the soil, less availability of soil nutrients, water and light etc. The possible reason for decrease in height with further increase in nitrogen rate could be due to the non-responsiveness of crops beyond certain levels and negative effects of excess nitrogen rates (Adas, 1978). The observed trend was in line with reports of Bunsgard *et al*. (1999) who stated that N is a constituent of many fundamental cell components and plays a vital role in all living tissues of the plant. Wurr.*et al.* (1999) concluded that increasing the application rate of N increased growth parameters of onion plant. Ahmed and Abdalla (2006) also showed that nitrogen application had increased plant height and yield.

The non- significant effect of intra row spacing on height of leek plant might be that the early growth stage, leaf formation phase, of the plant could possibly be due to leaf morphology and architecture or physiology that does not encounter light limitation as well as its shallow root system that does not encounter competition for nutrients and moisture (Brewster, 1977, 1994).

Table 1. The main effect of N- rate and intra row spacing on plant height, number of leaves, leaf length and pseudo-stem length of leek

Treatment	Plant height (cm)	Leaf length (cm)	Leaf number	Leaf width (cm)
Nitrogen (kg ha^{-1})				
0	61.02	50.19	10.57	3.16
69	63.34	51.28	10.40	3.23
92	64.64	51.89	10.78	3.37
115	64.18	50.11	10.34	3.13
138	60.79	48.59	10.26	2.81
LSD(0.05)	NS	NS	NS	NS
Intra row spacing (cm)				
5	63.34	50.38	10.54	3.21
10	61.65	49.94	10.35	3.05
15	63.39	50.91	10.51	3.16
LSD(0.05)	NS	NS	NS	NS
CV (%)	9.0	9.6	6.7	16.7

NS = means not significant at 5% probability level.

3.1.2. Leaf length and leaf number

The main effects of nitrogen rates and intra row spacing and their interaction on leaf length and leaf number of leek plants were found to be not significant in (Appendix table 3).

Even though the effect was non-significant, there was an increase in leaf length and leaf number with the increase in nitrogen rates up 92 kg N ha^{-1}; beyond this level, however, a trend of reduction was observed (Table 1). Maximum number of leaves per plant (10.78) was obtained due to the application of 92 kg N ha^{-1} while the least number of leaves per plant (10.26) was recorded from the application of 138 kg N ha^{-1}.

The result contradicts with the observation of Nasreen *et al* (2007) who reported that the application of 120 kg N ha^{-1} increased the number of leaves per plant and leaf length significantly over the control as well as lower levels of nitrogen. The result did not agree also with the report of Cuocolo and Berbieri (1988) who showed that leaf length increased linearly with increase in nitrogen rates from 46 to 120 kg N/ha. Similarly, Figliuolo *et al.* (2001) reported highly significant difference with respect to leaf length, and number of leaves per pant. Likewise, Nasreen *et al*. (2007) found that application of 120 kg N ha^{-1} increased the number of leaves per plant and further increase in the level of N (160 kg ha^{-1}) tended to decrease it on onion while Vachhani and Patel (1993) found the highest number of leaves per plant with the application of 150 kg N ha^{-1}.

The non significant response of leaf number in the present study can highlight that the site was not nitrogen deficient for leaf growth in leek. Furthermore, the possible reason for reduced leaf length and leaf number per plant with the increase of nitrogen beyond the 92 kg N ha^{-1} rate could be due to burning effect of the fertilizer at higher doses (Rizk, 1997).

Regarding the intra row spacing, inconsistent values that do not show trends were recorded in leaf length and leaf number. The maximum leaf length (50.38 cm) and leaf number per plant (10.54) were obtained from the intra row spacing of 5 cm; however, both values dropped at the 10 cm spacing and then slightly increased at the 15 cm. This result does not agree with the result of Singh and Schan (1999) on onion who reported that the greatest numbers of leaves per plant were recorded from the widest row spacing.. The results are similar to Weerasinghe *et al.* (1994), on onion.They reported that increasing plant competition significantly decreases seedling leaf number. Mari *et al.* (1997) and Rizk (1997) also reported mat lower planting density resulted in higher number of leaves per plant.

3.1.3. Leaf width

The statistical analysis of the data indicated that the main effects of nitrogen rates and intra row spacing as well as their interaction did not show significant effect on the leaf width of leek plants (Appendix table 3).

Similar to those of leaf number and leaf length, leaf width did not show trends in relation to population density. Leaf width was observed to be relatively lower in plants grown in numerical number at the 10 cm intra row spacing compared to those grown at 5 and 15 cm (Table 1).

The negative, but non-significant, response of leaf width growth of leek plants to the applied nitrogen rate could be attributed to effect of N in the synthesis of the different components of protein through increased production of carbohydrate in the plant system, which increases vegetative growth of plants (Verma *et al.,* 1994). This might be attributed to the fact that higher amount of nitrogen rate reduces competition for this resource and as a result leaves developed to larger sizes. This result is in conformity with that of Ahmed *et al* (2006) on onion.

Application of 69 kg ha^{-1} increased bulb diameter by about 11% as compared to the control (6.44 cm). Similar results were also reported by Yadav *et al*. (2003) who found that N at 150 kg ha^{-1} enhanced the formation of leaf diameters with highest diameter.

3.2. Yield and Yield Components

3.2.1. Pseudo-stem diameter

The analysis of variance indicated that the main effects of nitrogen rate and planting spacing as well as interaction of the two did not significantly affect pseudo-stem diameter (both white and green portions) (Appendix table 3). However, as revealed in Table 2, these results are contrary to (Tadesse, 2008) who obtained that the positive responses (inconsistence effect) of nitrogen to leek could be that N might have promoted more cell division and elongation which enables assimilation of more carbohydrates for further cell growth and elongation of shoots. The response in this study is in agreement with report of Tariq, (1999) and Biswas *et al.*, 2003) on onion. Similarly, Jilani *et al.* (2004) reported that the maximum leaf length of onion was recorded at 160 kg N ha^{-1} while the minimum leaf length was recorded at control level of nitrogen. Likewise, the growth in leaf length of *Iris germanica* was noted to be maximum with 23 g N m^{-2} where as minimum was recorded in unfertilized control plots.

3.2.2. Pseudo-stem length

The statistical analysis of data showed that the main effects of nitrogen rates and intra row spacing did not significantly affect the pseudo-stem length (white and green pseudo-stem parts), as shown in Appendix Table 3. Various studies result conducted in different countries reported that shank (shaft) length increases with increasing nitrogen rates. The tendency did not have a response in pseudo stem length of the green part of the leek. The decrease in pseudo-stem length could be due to the presence of high competition for growth factors at wider spacing

However, the actual result was in contradiction with Bungard *et al*. (1999) who described that N is the major constituent of proteins and the presence of abundant protein tends to increase the size of the leaves, and accordingly, bring about an increase in carbohydrate synthesis. Similar result was also reported by Jilani (2004) who found that N at the rate of 200 kg ha-1 enhanced the length of onion leaves.

As discussed earlier for other growth characters, the negative responses of leek to N could not have a direct relation with nitrogen fertilizer rates that promote cell division which enable assimilation of more carbohydrates for further cell growth, and thus, later shoot elongation in leek (Baker, 1998). Bungard *et al*. (1999) described that N is the major constituent of proteins and the presence of abundant protein tends to increase the size of leek leaves and accordingly bring about an increase in carbohydrate synthesis for elongation of the pseudo-stem. . As noted by Currah and Proctor (1990) the *Allium* crops in general require a constant supply of moisture throughout the growing season as their root system is inefficient. Sinnadurai (1978) also indicated that closer spacing results in smaller bulbs, while wider spacing increases bulb size

Table 2.The main effects of N- rate and intra-row spacing on pseudo-stem diameter, biological fresh yield weight (BFMY) and dry-matter content of leek

Treatment	Pseudo-stem diameter		Pseudo-stem length		Fresh Matter (BFMY) (g plant^{-1})	Dry matter (%)
	white (mm)	green (mm)	white (cm)	green (cm)		
N-rate (kg ha^{-1})						
0	28.18	28.88	6.32	15.93	72.70^{d}c	10.96
69	27.62	28.31	6.26	16.41	82.9^{ab}	11.27
92	29.53	30.23	5.56	17.01	99.30^{a}	11.64
115	28.75	28.99	6.10	17.48	83.20^{ab}	11.57
138	26.84	27.45	5.56	16.07	73.80^{d}	11.15
LSD(0.05)	NS	NS	NS	NS	26.60	NS
Intra row spacing (cm)						
5	28.38	29.03	5.78	16.49^{a}	88.10	11.91
10	27.59	28.03	5.72	16.56	78.60	10.83
15	28.58	29.25	6.38	16.69	80.40	11.21
LSD(0.05)	NS	NS	NS	NS	NS	NS
CV (%)	13.3	13.5	16.2	14.6	35.4	17.3

Means followed by the same letter within a column are not significantly different at 5% level of significance; NS= not significant.

3.2.3. Biological Fresh matter yield

As indicated in the Table 2, the biological fresh matter yield of leek significantly ($P<0.05$) varied due to the main effects of nitrogen rates while intra row spacing and its interaction with N did not have an effect on mean biological fresh matter yield of leek (Appendix table 5). The biological fresh matter yield showed significant increase with 12.3 and 19.8% when the nitrogen rates increased from 0 to 69 and 92 kg ha^{-1}, respectively (Table 2). Beyond the rate of 92 kg ha^{-1}, however, the fresh weight of leek per plant declined, although the rate of 115 kg ha^{-1} was significantly higher than plants from the control treatment. Significant difference was found between the nitrogen rates of 138 kg ha^{-1} (73.8g) and the control (72.7g).

Generally, a linear increment in biological fresh matter yield was observed with an increase in nitrogen rates from 0 to 92 kg ha^{-1}. In agreement with this result, previous studies have addressed the relationship between different N fertilizers and the growth characters of leek and related crops and that leek crop responds to good soil fertility and adequate fertilizer. For instance, Baker (1998) reported that N nutrient required by leek for optimum growth was 80 to 120 kg N ha^{-1}. The result is also in line with that of Booij *et al*. (1996) for leek and Brussels sprout and Melaku *et al*. (2010) for onion who reported similar responses to nitrogen rates. Nitrogen, being an integral part of chlorophyll and a constituent of all proteins, promotes vigorous vegetative growth (Ahmed, 2003).

3.2.4. Dry matter content

Statistical analysis of data indicated that the main effect of nitrogen rates, intra row spacing and their interaction did not significantly affect the dry matter content of leek pseudo-stem as shown in Table 2 and Appendix Table 5. The dry matter content in the (1.73%) unfertilized plots and under closer spacing might be slightly lower because of the competition for nitrogen and other nutrients which is needed for vegetative growth. The major pseudo stem lengths have uniformity in shape, sizes and their skin colour. Consequently, there was no change in carbohydrate production and accumulation in the storage of the pseudo-stem in this case. Furthermore, relatively more soil moisture is expected under wider spacing could be easily absorbed by the plants raise which subsequently reduce dry percentage of tissues because of dilution effect.

The non-significant difference observed in the dry matter content of leek pseudo-stem is similar with that of Hansen and Henriksen (2001) who noted that the dry matter content during the period from 10 to 100% top fall did not change significantly although there was a 44% increase in the yield of fresh bulb of onion. Similarly, Raupp (2005) indicated that nitrogen fertilization did not affect the dry matter content of pseudo-stem. In our experiment, the applied nitrogen doses did not have significant effect on the dry matter content. In spite of this fact, there were tendencies for the dry matter content to decrease slightly as the nitrogen level was increased. The portion of dry matter decreased from 11.97% at 0 to 11.60% at 46 kg N ha^{-1} (Table 2) Furthermore, the tendency of dry matter increases the growing period of onion decreased the dry matter content of the leaves and bulb in accord with results obtained by Sorensen (1999b); Preston and Sophea *et al* (2001 The researches pointed out that higher rate of nitrogen fertilizer decreased dry matter content in vegetables. Hansen and Henriksen (2001) also showed slight increase in dry matter that was due to loss of moisture from the outer surface whereas the reduction corresponded well to hydrolysis of fructans and termination of the dormancy period where the bulbs began to sprout

3.2.5. Marketable number of pseudo-stems per plot

ANOVA showed significant effect of nitrogen rates and intra row spacing on the number of marketable pseudo-stems per plot, while intra-row spacing showed highly significant ($P<0.01$) effects though their interaction was not significant (Appendix Table 5).

The significant effect of N could be the impact of the rate of nitrogen on the parameter. The possible reason for this might also be the less competition between the plants and efficient utilization of applied nitrogen and other growth factors for majority of the plants in the stand to develop pseudo-stems to a marketable size. Similar responses to N rate and intra row spacing were recorded for unmarketable (Table 3).However, the marketable pseudo showed increase with N application where rate at 69 and 92 kg N ha^{-1}, respectively, showed increment of 19.7% and 23.7% over the control. Pseudo-stem number also increased proportional to planting density employed. At the intra row spacing of 5 cm, marketable pseudo-stem number was about 105 and 225% higher than number from the spacing at 10 cm and 15 cm, respectively. The results of the present study support the findings of Maier *et al.* (1994) and Ahmed.*et al. (*2006) who stated that the marketable bulb of onion was increased as intra row spacing decreased up to 7.5 to 10 cm.

Table 3.The main effects of N- rate and intra row spacing on days to maturity and marketable, unmarketable of pseudo-stem number per plot leek.

Treatment	Days to maturity	Pseudo-stem number per plot		
		Marketable	Unmarketable	Total number
N-rate(kg ha$^{1)}$				
0	88.22^{d}	63.00^{b}	9.56	72.33^{a}
69	110.00^{c}	75.40^{ab}	10.11	86.33^{a}
92	119.78^{b}	77.90^{a}	8.33	86.22^{a}
115	128.78^{a}	75.30^{ab}	11.00	85.55^{ab}
138	131.67^{a}	75.66^{ab}	11.22	86.88^{b}
LSD (0.05)	5.36	14.78	NS	14.12
Intra row spacing (cm)				
5	113.50	122.90^{a}	12.73	135.66^{a}
10	116.53	59.70^{b}	8.86	68.53^{b}
15	117.10	37.80^{c}	8.53	46.20^{c}
LSD (0.05)	NS	11.45	NS	10.94
CV (%)	4.80	20.83	20.10	11.10

Means followed by the same letter within a column are not significantly different at 5% level of significance; NS = non- significant.

3.2.6. Unmarketable bulb number per plot

The main effects of nitrogen rates and interaction effects of N with intra row spacing did not show significant effect on the number of unmarketable pseudo-stems of leek. On the other hand, similar to the number of marketable pseudo-stems was highly significantly affected ($P<0.01$) by the intra row spacing and also the number of unmarketable pseudo-stems was non-significant effects ($P<0.01$) by the intra row spacing (Appendix Table 5).

Number of unmarketable pseudo-stems showed inconsistent trend with nitrogen rates. This result was in conformity with that of Berga *et al.* (1994) who stated that unmarketable yield might be controlled more importantly by other factors such as disease incidence, harvesting practice, etc. rather than by mineral nutrition. On the other hand, result of Abidissa *(*2008) showed that the application of N at a rate of 69 kg ha^{-1} decreased the number of unmarketable bulbs of onion by about 17% as compared to the untreated control which contradicts with observation in this study. The possible reason for the high unmarketable yield in closely spaced plants could be due to less inter-plant competition as compared to plants at wider intra row spacing. As described by Kanton *et al*. (2002), the reduction in number of unmarketable bulbs as intra row spacing increased might be attributed to the possible reduction in competition among the plants for soil moisture and nutrients. Forbes and Watson (1994) indicated that as intra row spacing increased, competition for available water, mineral nutrients and light increased. This result was in line with that of Geremew *et al* (2010) who reported that wider intra row spacing gave higher percentage of bulbs with larger bulb diameter.

3.2.7. Days to physiological Maturity

ANOVA showed the main effects of nitrogen rates significantly varied days to physiological maturity of leek while spacing and the interaction of the two did not significantly affect this parameter (Appendix Table 6.).

Days to physiological maturity showed significant increases with nitrogen application rate up to 115 kg N ha^{-1} that delayed maturity of pseudo-stem by 41 days. Even though statistically non-significant, increasing intra row spacing also tended to prolong days to 70% maturity stage of the leek crop where delay in maturity by 4 days was observed at 10 and 15 cm intra row spacing compared to those at 5 cm that matured in 113 days (Table 4).

Delayed maturity due to increased supply of nitrogen rates indicates longer favourable time for cell division, growth, photosynthesis, accumulation and eventual partitioning of photo assimilates to various plant parts (Marschner, 1995; Ahmed,*et al* 2003). The prolonged days to physiological maturity due application of nitrogen fertilizers might be due to the availability of nitrogen and its enhancing effect on absorption of other nutrients that could promote vegetative growth and delay maturity in many horticultural and field crops (Deukema and Vander Zaag,1990).

The present result was in line with reports by Rozek *et al.* (1990), Soujala *et al*. (1998) and Ahmed *et al* (2003) in case of nitrogen fertilizer application reported significant effect on days to 70% physiological maturity of onion.

3.2.8. Pseudo-stem yield

The main effects of nitrogen rates and intra row spacing showed a highly significant ($P<0.01$) effects respectively on the marketable and total pseudo-stem yield of leek; however both parameters did not vary due to the interaction effects of the treatments. The unmarketable pseudo-stem yield of leek was affected intra row spacing whereas the main factors of nitrogen rates and their interactions non significant differences were revealed in (Appendix Table 4).

Both marketable and total yields showed increasing trend with increase in nitrogen rates where the highest total marketable yield (46.68 t ha^{-1}) and total yield (48.63 t ha^{-1}) were recorded at the rate of 138 kg N ha^{-1}(Table 4). The increment in marketable yield ranged from 33% at 69 kg N ha^{-1} to 100% at 138 kg N ha^{-1} compared to the yield from the unfertilized control (23 t ha^{-1}). Similar trend was also recorded for the total pseudo- stem yield (Table 4). This fact implies that there might have been response to even higher levels of application of nitrogen.

The possible reason for increase in the pseudo-stem yield of leek with increase in nitrogen rate could be that plants effectively utilized the applied nitrogen which might further enabled absorption of other nutrients. Similarly, Brady and Wiel (2002) noted that a good supply of nitrogen stimulates root growth and development as well as the uptake of other nutrients. Nitrogen is a main component of many essential plant compounds and it is needed to form chlorophyll, proteins, amino acids and many other molecules essential for plant growth and other critical nitrogenous plant components such as the nucleic acids and chlorophyll (Marschner, 1995). Hence, the availability of nitrogen and its enhancing effect on absorption of other nutrients as well its promotion vegetative growth and delay in maturity is expected to maximize assimilate production and partitioning to the storage tissue, the pseudo-stem in this regard (Rogers,1977**.**).

The present result was in line with reports by Rozek *et al.* (1990) and Ahmed *et al*(2003) who state that the total yield per hectare increased as plant density increased although yield of the individual plants and their components were significantly reduced suggesting a compensation of higher plant densities on yield in onion.

The increased yield at higher densities is due to the fact that more pseudo-stems were harvested per unit area of land. At higher planting densities, the ground is covered with green leaves earlier, light is intercepted and used for assimilation, fewer lateral leaves are formed and pseudo-stem growth starts earlier, which enables to produce more medium and smaller pseudo-stem.(Beukema and Vander Zaag,1990). However, decreases in yields as a result of wider spacing could be compensated in part by an increase in large-size pseudo-stems and a decrease in small pseudo-stems yields (Rees *et al,* 1987).

Table 4. The main effects of N- rate and intra-row spacing on days to maturity and marketable, unmarketable and total yield of leek

Treatment	Pseudo-stem yield (t ha^{-1})		
	Marketable	Unmarketable	Total
N-rate(kg ha[1)]			
0	23.00[e]	1.28	24.27[e]
69	30.57[d]	1.59	32.16[d]
92	35.48[c]	2.02	37.51[c]
115	41.47[b]	2.15	43.62[b]
138	46.68[a]	1.95	48.63[a]
LSD (0.05)	4.25	NS	4.08
Intra row spacing (cm)			
5	36.76	2.40[a]	39.16[a]
10	35.92	1.61[b]	37.53[ab]
15	33.63	1.39[b]	35.0[2b]
LSD (0.05)	NS	0.50	3.16
CV (%)	12.43	37.40	11.30

Means followed by the same letter within a column are not significantly different at 5% level of significance; NS = non- significant.

6. REFERENCE

Abbey, L., R. Kanton and H. Braimah, 1998. Susceptibility of shallot to the timing and severity of leaf damage. *Journal of Horticultural Science and Biotechnology 73: 803-805.*

Abdissa Yohannes (2008).Effects of Nitrogen and Phosphorus Rates on Growth, Yield, Quality and Storability of onion (Allium cepa l.) on Vertisols of Shewa Robit, Msc thesis Msc thesis presented to school of Graduate Studies of Haramaya University.

Adas (1978). Dry bulb onions (*Allium cepa* l.. Horticultural Enterprises Booklet 1 (4th edition), MAFF,Pinner, Middlesex, UK.

Ahmed, I.H. and A.A. Abdella, 2006. http://www.actahor.org/books/143/143_9.htm. Nitrogen and phosphorus fertilization in relation to seed production in onion Allium cepa L. ISHS. *Acta Horticulturae 143: VIII. African Symposium on Horticultural Crops.*

Ahmed, S., Ahmed, F., Hussain, F., Hussain, M. 2003. Effect of different NPK levels on the growth and yield of kohlrabi (*Brassica cauloropa* L.) at northern areas of Pakistan.As. Jour. Plant Sc., 2, 3: 336-338.

Aklilu, S., 1997. Onion research and production in Ethiopia. *Acta Hortiulturae*, 433: 95-98

AL-Jamal, M.S., Sammis, T.W., Ball, S. and Smeal, D., 2000. Computing the crop water production function for onion. *Agri. Water Manage.,* 46: 29-41.

Archer J (1988). Crop Nutrition and Fertilizer Use. Second Edition. Farming Press Ltd. Wharfedaale Road, Ipswich, Suffolle.

Augusti, K.T., (1990). Therapeutic and medicinal values of onions and garlic. In: Brewster, J.L.,

Availableonlinehttp%3A%2F%2Fwww.pcmgtexas.org%2Fvegetable_cultivars_for_north_central_texas.pdf).claim.

Badarudin, B. and A. Haque. 1977. Effect of time of planting and spacing on the yield.

Baker, R. 1998. Leek production (July, 1998), http://www.gov.on.ca/OMAFRA/ english/crops/facts/ (07. Aug. 2005).*Baumann, D.T., Bostioans and M.J. Kropff, 2001. Competiton and crop performance in a leek-celery intercropping system. Crop science, 41:764-774.*

Berga Lemaga, Gebremedhin W/Georgis, Terrisa Jalleta and Bereke-Tsehai Tuku. 1994a. Potato Agronomy Research. **In:** Edward Herath and Lemma Dessalegn (Eds.). *Proceedings of the Second National Horticultural Workshop of Ethiopia*. Addis Ababa, 1- 3 December 1992. Institute of Agricultural Research and Food and Agriculture Organization, Addis Ababa, Ethiopia.

Biczak, R., Grul, E., Herman, B. 1998. The effect of NPK fertilization on yield and content of chlorophyll, sugars and ascorbic acid in celery. Folia Hort., 10, 2: 23-34.

Biswas, S.K., P.K. Sarker, A. K. M, Mazharulislam, M.A. Bhuyan and B.C. Kundu, 2003. Effect of irrigation on onion production. *Pakistan J. Biol. Sci*. 6(20): 1725-1728.

Biswas, T. D., and S. K. Mukherjee, 1993. Text Book of Soil Science. (5th ed.). Tata McGraw-

Black, C. and Ong, C., 2000. Utilization of light and water in tropical Agriculture. *Agri. Meteorol.* 104: 25-47.

Block, E. (1992) The organosulfur chemistry of the genus *Allium* – implications for organi sulfur chemistry. *Angewandte Chemie, International Edition in English* 31, 1135–1178.

BOARD (SNNPRS Bureau of Agriculture and Rural Development) (2008).Analysis of production of ginger.Unpublished data.

Booij R, Kreuzer ADH, Smit AL, van der Werf A. 1996. Effect of nitrogen availability on dry matter production, nitrogen uptake and light interception of Brussels sprouts and leeks. Netherlands Journal of Agricultural Science 44: 3±19.

Brady and Wiel (2002). Growing onions, Garlic, Leeks and other Alliums in Wisconsin: A guide for fresh market growers (A3785). University of Wisconsin- system Board of Regents and University of Wisconsin-Extension, Cooperative Extension.

Brewster, J.L., 1977. The physiology of the onion. Horticultural Abstracts 47: 17-23.

Brewster, J.L., 1982. Growth, dray matter partition and radiation interception in an overwintered bulb onion crop. Annuals of Botany, 49: 609-617.

Brewster, J.L., 1994. Onions and Other Vegetable *Alliums*. CABI Publishing. Wallingford, UK. 236p.

Brittain, M. (1988) Leeks-the long and the short of it. *The Grower* 110(3), 20–23.

Brunsgard, G., Sorensen, J.N., Kaack, K., Eggum, B.O.1997. Protein quality and energy density of leek (*Allium porrum* L.) as influenced by water and nitrogen supply and plant age at harvest. *J. Sci. Food & Agri*., 74, 2: 237-243.

Bungard RA, Wingler A, Morton JD, Andrews M (1999). Ammonium can stimulate nitrate and nitrite reductase in the absence of nitrate in Clematis vitalba. Plant Cell Environ., 22: 859-866.by nitrogen and water stress. *Journal of Horticultural Sciences and Biotechnology,* 76: 501-

Casey, S. and Garrison, N., 2003. Onion: Description and growing tips. Master gardeners of Santa Clara County.University of California Cooperative Extension, SanJose. http://www.mastergardeners.org

Clemente,R.,Paredes, C. And B ernal, M. P. 2007. A field experiment investigating the effects of olive husk and cow manure on heavy metal availability in a contaminated calcareous soil from Murcia. Agriculture Ecosystems and Environment 18; 318-326.

Cockshull, K.E., 1988. The integration of plant physiology with physical changes in the greenhouse climate. *ActaHorticulturae*, 229: 113–123.

Corgan, J., M. Wall, C. Cramer, T. Sammis, B. Lewis and J. Schroeder, 2000. Bulb Onion Culture and Management. NMSU Agricultural Experiment Station Circular 563: 1-16.

Crozier, A., Clifford, M., and Ashihara, H. (2006). Plant Secondary Metabolites: Occurence, Structure and Role in Human Diet. Oxford: Blackwell, 384 pp.

CSA (Central Statistical Authority), 2008. Report on Land Utilization. Statistical Bulletin, Vol.417. Addis Ababa, Ethiopia.341p.

*Fallorusso,E.,Lanzotti, Y.,Taglialtcolo-Scafati, O.,Cicalo, c.(2001).The flavonoids of Leek Allium porrum, phytochem. 57,565-569.*http://foodforbreastcancer.com/foods/onions-and-garlic January 1, 2012.

FAO (2007). *Agriculture Production and Trade Statistics*. Food and Agriculture Organization of the United Nations, Rome (available at: http://faostat.fao.org).

FAOstat, 2010. FAO. Production year Book for India vol 67 Food and Agriculture Organization of the United Nations, Rome Italy. 17: 11-12.
Farragg, M.M., 1995. Influence of planting method and plant density on growth, yield and bulb quality of onion grown from sets. Assiut J. Agri. Sci. 26: 73-84.
Figliuolo, G., V. Candido, G. Logozzo, and P.L.S. Zeuli, 2001. Genetic Evaluation of Cultivated garlic Germplasm. *Euphytica.* 121(3):325-334.
Forbes, J. C. and R. D.Watson. 1994. Plants in Agriculture. 2nd ed. Cambridge University Press, Cambridge.
Frank J., Dave B., Bekele Wolde and Lemma Desalegn (2011).Assessment of development potentials and investment options in the export-oriented fruit and vegetable sector.p1-17.
Frappell, B. D., (1976). Plant spacing of onions. *J. Hort. Sci*. 48: 19-28.
George R.A.T, 1985, Vegetable seed production. Longman Group, Ltd., London.
Geremew Awas, Teshome Abdisa, Kasaye Tolesa and Amenti Chali, 2010. 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. 2(1) 7-11.
Getachew, T. and Asfaw, Z., 2000. Research achievements in garlic and shallot. *Research Bull. Report No.36. EARO, Ethiopia.*
Grime, J.P., 1979. Plant strategies and vegetation processes. John Wiley, Chichester.
Grubben, G.J.H., 1997. Constraints for shallot, garlic and Welsh onion in Indonesia: A case study on the evolution of *Allium* crops in the equatorial tropics. *Acta Horticulturae. 358: 333-340.*
Gupta, S.S.S. and M.A. Gaffar, 1980. Effect of row spacing and different combinations of NPK fertilizer on the yield of onion. Bangladish Hort., 8: 8-12.
Hanelt, P., 1990. Taxonomy, evolution and history .In: Rabinowitch, H.D. and J.L. Brewster (eds.), Onions and Allied Crops vol.1. CRC Press, Boca Raton, Florida, pp. 1-26.
Haque, A., M.R. Takulder, and M.A. Miah, 1979. Effect of plant and row spacing on size, weight and yield of onion. Bangladish J. Agric., 4: 147-150.
Hasen,S.L.,and K. Henriksen,2001.increasing the dry matter production in bulb onion(Allium cepa L) Denmark Department of fruit,Vegetable and Food Science.2:147-152.
Hayashi, Y. and R. Hatano, 1999. Annual nitrogen leaching to sub surface water from clayey aquic soil cultivated eith onions in Hokkaido, Japan. Soil Science and Plant nutrition, 45: 451-459.
Henry, L.T. and J.C.D. Raper. 1989. Effects of Root Zone Acidity on Utilization of Nitrate and Ammonium in Tobacco Plants. *J. Pl. Nutr*., 12 (7): 811-826.
Hołubowicz R., 2005, Przewodnik do ćwiczeń z nasiennictwa roślin warzywnych. Wyd. AR w Poznaniu.
Hussen, J., 1997. Influence of nitrogen and maleic hydrazide on the keeping quality and subsequent establishment of shallot. M.Sc thesis. pp. 11-13.
Islam, M., 1988. Effects of different doses of nitrogen and plant spacing on the growth and yield of onion (Allium cepa L.). M. Sc. (Ag) Diss., Dept. of Horticulture, BAU, Mymensingh, Bangladesh.
Jilani MS (2004). Studies on the management strategies for bulb & seed production of different cultivars of onion (*Allium cepa* L.). PhD thesis, Gomal University, Dera Ismail Khan.
Keating, B.A.and P.S. Carberry, 1993. Resource capture and use in intercropping: solar radiation. Soil, 141: 119-135.
Kebede Woldetsadik, 2003. Shallot (*Allium cepa* var. ascalonicum) Responses to Plant Nutrients and Soil Moisture in a sub-humid Tropical Climate. Doctoral Thesis. Swedish University of Agricultural Sciences, Alnarp, Sweden.
Keeny, D. R., 1995. Nitrogen management for maximum efficiency and minimum pollution. pp. 605-649. In: F.J, Stevenson (ed.). Agronomy: Nitrogen in agricultural soils. Madison, Wisconsin, USA.
Konesky, D.W., M. Y. Siddiqi, A. D. M. Glass and A. I. Hsiao, 1989. Genetic Differences Among Barley Cultivars and Wild Oats Lines in Endogenous Seed Nutrient Levels; Initial Nitrate Uptake Parts, and Growth in Relation to Nitrate Supply. *J. Pl. Nutr*. 12 (1): 9-35.
Kristensen, H.L., Thorup-Kristensen, K. 2004. Root growth and nitrate uptake of three different catch crops in deep soil layers. *Soil Sci. Soc. Am. J., 68: 529-537.*
Lancaster, J.E. and M.J. Boland, 1990. Flavour Biochemistry. pp 33-72. In: H.D.
Larkcom, J. (1991). *Oriental Vegetables*. John Murray, London.
Lemma, 2004. Onion Production Pamphlet (Amharic version). EARO, Melkassa Research Center.
Lemma, D. and Herath, E., 1992. Agronomic studies in Alliums Presented at 2nd National *Horticultural work Shop,* December, 1992. IAR, Addis Ababa.
Lemma, D. and Shemelis, A., 2003. Research Experiences in Onion production. EARO, p.123.
Levy, D. Ben-Herut, Z., Albasel, N. Kaisi, F. and Manasra, I., 1981. Growing onion seeds in an arid region: drought tolerance and the effect of bulb weight, spacing and fertilization. Scientia Horticulture 14:1-7.
Maier, N.A., A.P. Dahlenburg, and C.M.J. Williams. 1994. Effects of nitrogen, phosphorus and potassium on

yield and petiolar nutrient concentrations of potato (*Solanum tuberosum* L.) cv. Kennebec Atlantic. *Australian Journal of Experimental Agriculture*. 34: 825-834.

Marschner, H., 1995. Mineral nutrition of higher plants. second edition., pp: 285-299. Academic Press, London.

Meer W.J. Ridgman and Hanley, F.. 1990. The effects of fertilizers on the bulbing of formation Onion. *Journal of Agricultural Sciences* 65: 159-169.

Mehla, C.P., K.S. Bastwana, B.S. Saharan, and J.S. Taya,1993. Effect of row spacing and nitrogen levels on growth and yield of onion. Hort.,Record. 25: 139-141.

Melaku Fisseha,(2010). Pesponse of onion (Allium cepa var. cepa) to combned Application of Farmyard Manure and Inorganic Nitrogen and Phosphorus Fertilizer at Alage Ethiopia. Msc thesis presented to school of Graduate Studies of Haramaya University.

Menzel, C.M., 1985. Tuberization in potato at high temperature: interaction between temperature and irradiance.Annuals of Botany, 55:35-39.

Metasebia, M. and H. Shimelis, 1998. Proceeding of the 15th Annual Research and Extension Review Meeting, 2 April 1998. Alemaya Research Centre. Alemaya University of Agriculture. pp. 216-235.

Mohamed, K., 2010. Allium improvement for the tropics: Problems and AVRDC strategy. Proceeding of the first International Symposium. on Allium for the Tropics, Acta Hortc.58:79-86.

Mondal, M.F., 1985. Studies on the control of bulbing in onion (Allium cepa L.). PhDThesis, University of Birmingham, UK.

Mondal, M.F., Brewster, J.L, Morris, G.E.L. and Butler, H.A., 1986. Bulb development in onion(Allium cepa L.). Effects of the size of adjacent plants. Shading by neutral and leaf filters, irrigation and nitrogen regime and the relationship between the red: far red spectral ratio in the canopy and leaf area index. Annuals of Botany, 58:207-219.

Monteith, J.L.,1994. Validity of the correlation between intercepted radiation and biomass. *Agric. For. Meteorol*. 68: 213–220.

Murphy HF (1968). A Report on Fertility Status of Some Soils of Ethiopia. HSIU/College of Agric. Alemaya. Experiment Station. Bull. No. 44.

Murphy, H.F., 1959. A Report on Fertility Status of Some Soils of Ethiopia. HSIU/College of Agric. Alemaya. Experiment Station. Bull. No. 1.

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

Neeteson, J.J., R. Booij, A. P. Whitmore, 1999. A review of sustainable nitrogen management in intensive vegetable production systems. *Acta Horticulture,* 506-17-28.

Nelsan, D.W. and I.E. Sommers, 1982. Total carbon, organic carbon and organic matter. Chemical and microbiological properties, Am. Soc. Agron. 9: 639-679

Norman, A. G., 1963. Competition among crops and pasture plants, Adv in Agronomic. 15:1-1

Olsen, S.R. and L.E. Sommer, 1982. Phosphorus. In: A.L. page, R.H, Miller and D.R. Keeneys (eds). Pp 403-430. Method of soil analysis chemical and biological properties; Am. Soc.

Panhwar F, 2004. The role of Nitrogen Fertilizer in Agriculture. Digitalverlag Gmbh. Germany. http://www.Chemlin. Com.

Pathak, C.S. 1994. *Allium* improvement in the tropics: Problems and AVRDC Strategy. *Acta. Hort.,* 358:23-29.

Pelter, Q., Mittelstadt, R., Leib, B.G. and Redulla, C.A., 2004. Effect of stress at specific growth stages on onion bulb yield and quality. *Agri Water Manage,* 68: 107-115.

Rabinowitch, H.O. and L. Currah, 2002. Allium Crop Science: Recent Advances. CABI Publishing. U.K. 585p.

Randle, W.M. and C.A. Ketter, 1998. Pungency assessment in onions. Proceedings of the 19 workshop conference of the Association for Biology Laboratory Education (ABLE). pp177- 196.

Rao MR, Niag A, Kwcsiga F, Duguma, B, Frazel S, Jama B, Buresh R (1998). Soil Fertility Replenishment in Sub-Saharan Africa. *In*: Londoen D (ed.) Agro forestry Today. No. 2. International Center forResearch in Agroforestry (ICRAF), UK, 10: 2-5.

Rashid, M.A. and M.M. Rashid, 1978. The effect of spacing on the yield of onion. *Hort. Abst.,* 48: 481.

Raupp, J. 2005. Fertilization effects on products quality and examination of parameters and methods for quality assessment. (April, 2000), http://www.edis.ifas.ufl.edu (07. Aug. 2005).

Rees, A.R., Bleasdale, J.K.A. and Wallis, L.W. 1987. Effect of spacing and flower on bulb yield of Narcissus. *J. Agri. Sci.* 43:113-120.

Reiley HE, Shry CLJ (1979). Introductory Horticulture. Delmar Publisher. Albany, New York.

Rice RP, Rice LW, Tindall HD (1993). Fruit and vegetable production in warm climates. The Richardson HL (1968). The Use of Fertilizers: The Soil Resources of Tropical Africa. Moss RP (ed.). Cambridge University Press, p. 138.

Rizk, F.A. 1997. Productivity of onion plant (*Allium ccpa* L.) as affected by method of planting and NPK application. Egypt J. Hort. 24 (2): 219-228.

Rogers, I.S., 1977**.** The influence of plant spacing on the frequency distribution of bulb weight and marketable yield of onions. *Journal of Horticultural Science,* 53: 153-161.

Rozek, K.S., R.V Sen, B.R. Yadav, 1990. Response of onion to nitrogen and potassium fertilization under semi-arid condition. *Indian Journal of Horticulture*, 50(4): 146-158

Rubatzky, V.E. and M. Yamaguchi, 1996. World vegetables. Principles, production and nutritive values. 2nd ed. International Thomson publishing. New York. 284p.

Sale, P.J.M., 1976. Effect of shade at different times of growth and yield of potato. Australia Journal of Agricultural Research, 27: 567-574.

Seiger, DS. (1998). Plant Secondary Metabolism. Dordrecht: Kluwer Academic, 529 pp.

Shimelise, A., 2003. Study on Flower and Seed Production Potential and Association of Characters with Seed Yield in Onion (*Allium cepa L.).* An MSc Thesis Presented to the school of Graduate Studies of Alemaya University. 160p.

Shock, C.C., Feibert, E.B.G. and Saunders, L.D., 1998. Irrigation management for drip irrigated onions.http//www.cropinfo.net.

Shock, C.C., Feibert, E.B.G. and Saunders, L.D., 2004. Effect of short- duration water stress on onion single centeredness and translucent scale. Malheur experiment station, Oregon State University, Ontario.

Simon, P.W., 1992. Onion Improvement Newsletter for 1991. Dept of Horticulture, Universityof Wisconsin, Madison, Wisconsin, USA.

Singh, N.P., and R.A. Singh, 2002. Scientific crop production, X press Graphics, Delih- 28, 1st ed., India

Singh, R.V., 1995. Response of onion to plant spacing, nitrogen phosphorus fertilisation. *J Research Bisra Agric. Uni*., **7**: 141-143.

Singh, S.R. and B.P. Sachan. 1999. Evaluation of different bulb size, spacing and varieties for higher seed yield and yield attributing traits on onion (*Allium ccpa* L.). Crop Res. Hisar. 17 (3):351-355.

Sinnadurai, 1978. Improvement of local cultivars of onions and shallots. Crop improvement in Ghana: proc.of a Symp. Legon, Ghana.

Sophea, K., Preston, T.R. 2001. Comparison of biodigester effluent and urea as fertilizer for water spinach vegetable. Liv. Res. for Rur. Dev., 13, 6: 1-13.

Sorensen, J.N. and K. Grevsen, 2001. Sprouting in bulb onions (*Allium cepa* L.) as influenced

Sørensen, J.N., 1999a. Improve in N efficiency in vegetable production by fertilizer placement and irrigation. *Acta Horticulturae 428: 131-140.*

Sorensen, J.N., 1999b. Nitrogen effects on vegetable crop production and chemical composition. *Acta Hort., 506: 41-49.*

Sulistiorini, D. & van der Meer, Q.P., 1993. Allium ampeloprasum L. cv. group Leek. In: Siemonsma, J.S. & Kasem Piluek (Editors). Plant Resources of South-East Asia No 8. Vegetables. Pudoc Scientific Publishers, Wageningen, Netherlands. pp. 62–64.

Suojala, T., T. Salo and R. Pessala, 1998. Effect of fertilization and irrigation practices on yield, maturity, and storability of onions. *Agricultural and Food Science in Finland 7: 477-489.*

Tadesse Adgo Mihiretu (2008). Farmers' evaluation and adoption of improved onion production package in Fogera District, South Gondar, Ethiopia. (IPMS theses. Accessed 02.06.2010).

Takele D.,2004.Assesement of species composition of thrips (thysanoptera: thripidae) on onion and their management using onion varieties and mulches in the rift valley. Msc thesis presented to school of Graduate Studies of Haramaya University.

Tamirat Tesema,(2006).Effect of Nitrogen and Phosphorus Application on seed yield and Nutrient uptake of onion (*Allium cepa* var *cepa*) on black soil of Agarfa, South Eastern highland Msc thesis presented to school of Graduate Studies of Haramaya University

Tamiru Hirpa, 2001. Effects of plant population and harvesting time on tuber yield of two Varieties of potato (*Solanum tubersome* L.). An M.Sc.Thesis presented to the School of Graduate Studies of Alemaya University. 84 p.

Tariq,M.,1999. Effect of different N levels a lone and in combination with constant doses of P ansd K on iris Msc(H) Thesis,Drptt. Of Hort.NWFP Agric.Univ. Peshawar.

Theunissen, J., Schelling, G. 1998. Infestation of leek by thrips tabaci as related to spatial and; temporal patterns of undersowing, BioControl, 43, 1: 107-119.

Treoh, F.R. and L.M. Thompson, 1993. Soils and Soil Fertility (5th ed.). Oxford University Press, New York.

Tzeng, S.H., Ko, W.C., Ko, F.N., Teng, C.M., (1991). Inhibition of platelet aggregation by some flavonoids. Thrombosis Research 64, 91–100.

Vachhani, MU, Patel ZO (1993). Effect of nitrogen, phosphorus and potash on bulb yield and quality of onion (*Allium cepa)*. Indian J. Agro., 3: 333-334.

Van Eeden, F.J., Myburgh J., 1971**.** Irrigation trials with onions. *Agroplantae* 3: 57-62.

Verma, T.S., R. Chand, P.C. Thakur, K.D. Lalkhanpal, A. Singh, R. ('hand and A. Singh. 1994. Effect of bulb size and plant spacing on seed yield of onion. Ind. J. Hill Farming. 7(1): 102-104.

Visser, C.I. M., 1998. Effect of split application of nitrogen on yield and nitrogen recovery of spring-sown onions and on residual nitrogen. *Journal of Horticultural Science and Biotechnology,* 73: 403-411.

Vohra, S.B., M. Rizaman and J.A. Khan., 1994. Medical uses of common Indian vegetables. *Planta Medea*., 23(4): 381-393.

Voss, R.E. and Mayberry, K., 1997. Green onion production in California. Publication No. 7243, University of California, Division of Agriculture and Natural Resources. Oakland, California, USA.

Weerasinghe, S.S., R. Fordhan, I, Babik and J. Rumpel.1994. The effect of plant density on onion established from multi-seeded transplants. 7th int'l. Symp. on timing field production of vegetables,Skiemicwice,Poland.Acta Horticulturae. 371: 97-104.

Willey, R.W., 1990. Resource use in intercropping systems. Agricultural and Water management, 17: 215-231

Wurr, D.C.E., Fellows, J.R., Hambidge, A.J. and Fuller, M.P. (1999) Growth, development and bolting of early leeks in the UK. *Journal of Horticultural Science and Biotechnology* 74, 140–146.

Yadav, R.L., N.L Sen, B.L. Yadav, 2003. Response of onion to nitrogen and potassium fertilization under semi-arid condition. *Indian Journal of Horticulture*, 60(2): 176-178.

Yeshi Muluneh, 2003**.** Influence of bulb size and nitrogen application on growth, yield and quality of shallot (*Allium cepa* L.var. *ascalonicum*) on Alemaya Vertisol. M.Sc.Thesis submitted to the School of Graduate Studies of Alemaya University. 80p.

Yohannes Abebe. 1987. Current activities, research recommendations and Future strategies of onion research in Ethiopia. pp. 358-367. Proceeding of 19th National crop improvement conference. Ethiopia, Addis Abeba , 22-26 April 1987. Institute of Agricultural Research.