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Review on the effects of phosphorus on growth and yield of onion (*Allium cepa* L.)

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Abstract
Onions (*Allium cepa* L.) are biennial herbaceous plant of the family Alliaceous that are typically grown as annuals. Globally, onions were produced at nearly 35 millions tones per annuals. In Ethiopia, it is widely grown in the rift valley and lakes regions of the country. The objective of this seminar is to review the effects of different level of phosphorus on growth and yield of onion. Phosphorus fertilizer is one the most complex production in many tropical soils, owing to low native content and phosphorus immobilization with the soil. In onion, phosphorus deficiencies reduced root and leaf growth, bulb size and yield and also delay maturation. In the soil the amount of phosphorus is moderately low. Onion growth and yield can be enhanced by applying phosphorus. The use of optimum phosphorus fertilizer is one of the prominent to increase production. Still optimum rate of phosphorus fertilizer is not well identified. To optimize phosphorus availability through phosphorus addition, soil factors must be considered and research should be focused on the level of phosphorus on growth and yield of onion.

Keywords: Phosphorus, onion, *Allium cepa* L.

Introduction
Onions (*Allium cepa* L.) are biennial herbaceous members of the family Alliaceae that are typically grown as annuals. It belongs to the genus Allium which contains 300 species which are widely distributed in northern temperate region. They are native to southern Asia and have long been valued in China and India for their flavorings (Henelt, 1990) [16].

Globally, onions were produced at nearly 35 million tones per annual (FAO, 2005). In Ethiopia, it is widely grown in the rift valley and lakes region of the country (Lemma and Shimeles, 2003) [18]. The total area under onion production in Ethiopia was estimated to be 15,628.4 hectare with total production of 1.48 million quintals (0.148 million tones). The average onion production in the year 2008 is 7.9t/ha (CSA, 2009) [11].

Onions are cool season crop adapted to wide range of temperature and can withstand short exposure to temperature well below freezing. Optimal production is obtained at cool temperature 55 to 77 °C and is grown on much too heavy clays. Onion plant is sensitive to high acidity and produces maximum yield over fairly narrow ranges of soil texture, on sandy loam soil and on long island it is reported that onion produced at maximum PH of 5.8 – 6.5 (Halliburton, 1996) [15].

Onion is one of the most important condiments, being widely used in green form or as mature bulb or both salad and for preparation of a number of dishes likes: soups, sauces and for seasoning of foods. Mild flavored or colorful bulb onions are often chosen for salads (Khan, *et al.*, 2005) [17]. Onion used for flavor, aroma and taste in preparation of vegetables, in the form of dehydrated, freezing, canning and pickling (in vinegar or brine); onion is free from microbial contamination and used for food manufacture (Rai and Yodav, 2003).

Varieties with high total soluble solutes (TSS) content are convenient for processing in the farm of dehydrated slices. Consumer often has very strong local preferences for size, shape and bulb of onion (Curran and Proctor, 1990) [13]. The productivity of onion in farmers field ranges between 9 and 15 t/ha which is for less than the yield obtained under research area which is 30-35 t/ha (Lemma and Shimelis, 2003) [18]. This can be due to many factors. The most important factors are lack of optimum levels of phosphorus fertilizers (Abdisa *et al.*, 2011) [1]. Phosphorus fertilizer is one the most complex in production in many tropical soils, owing to low native content and high phosphorus immobilization with in the soil. Phosphorus is essential for root development.

When availability is limited, plant growth is usually reduced. In onion, phosphorus deficiencies reduced root and leaf growth, bulb size and yield also delay maturation (Abdisa *et al*., 2011) [1]. Onion growth and yield can be enhanced by applying phosphorus. Onions are more susceptible to nutrient deficiencies than most crop plants because of their shallow and unbranched root system; hence they require and often respond well to addition of fertilizer (Brewester, 1994).

Onion is grown in most parts of Ethiopia but, a lot of constraints have contributed to the low yield. Phosphorus deficiency is one of the main constraints to onion production in many tropical soils, owing to low content and high phosphorus immobilization with in the soil. The use of sub-optimal phosphorus fertilizers is one of the prominent to mention. Still optimum rate (level) of phosphorus fertilizer is not well identified. So farmers set low yield and poor quality of onion. To this effect, this seminar paper is aimed to review the effects of different phosphorus level on growth and yield of onion. The objective of this senior seminar paper is to review the effect of different phosphorus level on growth and yield of onion.

Onion crop

Onion (*Allium cepa* L.) is an herbaceous biennial monocot cultivated as an annual. Onion is being a biennial crop takes two seasons for seed production. During the first season bulbs are formed while flowers, stalks and seeds are developed in the second season. Onion is grown mainly for its bulbs; although the green shoots of salad onion is also an important part. It can be grown in all types of soils. But, for higher yield drained loam soil with a PH of 6.0 to 6.8 is good (Brewester, 1994).

The onion bulb consists of the swollen bases (sheaths) of bladed leaves surrounding swollen bladeless leaves. Each leaf consists of a blade and sheath; the blade may or may not be distinctive. The sheath develops to encircle the growing point and forms a tube that encloses younger leaves and the shoot apex. Collectively, the grouping of these sheaths comprises the pseudo stem. Leaves a rise from the short, compressed, dislike stem which to increase a diameter with maturation and resembles an inverted cone. The onion skin is formed from the dry paper like outer most leaf scales that lose their freshness during bulbing. Major bulb features are uniformity of shape, size and skin color, pungency and dry matter content (Brewester and Rabinowitch, 1990; Rubatzky and Yamaguch, 1997).

Importance and production prospective of onion in Ethiopia

Onion (*Allium cepa* L.) is an important bulb crop in Ethiopia. Onion was introduced to the agricultural community of Ethiopia in the early 1970's when foreigners brought in. Though shallots are traditional crop in Ethiopia onion is becoming more widely grown in recent year (Table 1). It is widely produced by farmers and commercial growers throughout the year for local use and export market. Onion is valued for its distinct pungency and form essential ingredients for flavoring varieties of dishes, sauces, soup, sandwiches, snacks as onion rings etc. It is popular over the local shallot because of its yield potential per unit area, availability of desirable cultivars for various uses, ease of propagation by seed, high domestic (bulb and seed) and export (bulb, cut flowers) markets in fresh and processed forms. Ethiopia has high potential to benefit from onion production. The demand for onion increases from time to time for its high potential to benefit from onion production. The demand for onion increases from time to time for its high bulb yield, seed and flower production potential (Lemma and Shimelis, 2003) [18]. Over the last 15 years the total surface area dedicated to onion crop in the world has doubled and presently reaching 2.74 million hectare. Average world yield increased from 12 t/ha in the early 1960s to 17 t/ha in 2001. As a result of the increases in cultivated area and the yield obtained the world production of onion is about 3944 million tons per year (FAOSTAT, 2011).

Table 1: Area harvested and production of onion by year in Ethiopia for the last five years.

Year	Average production (ha)	Production (ton)
2012	16,579	1,784,745,919
2013	21,392	12,178,474
2014	21,392	178,474
2015	18,013	175,106
2016	17,588	169,317

Source; FAOSTAT, 2015 and MoARD, 2016

The production of vegetable is becoming important with the expanding irrigated agriculture and with the growing awareness on the importance of the sector as source of income, improved food security, sources of raw materials for industries generates employment opportunity because it demands large labor force. The expansion of water harvest schemes in small farmers sector and irrigated agricultural development projects have made significant contribution to the development of the sector. The success of production depends on the adaption of improved technologies such as cultivars that have acceptable standard and high value in the local use and export markets (Lemma *et al.*, 2006).

Irrigation development is part of the strategy designed to ensure food security and alleviate poverty in Ethiopia including Jimma zone. In 2009/10 production season there was about 79.52 ha of land covered by onion production in the zone. There are 9146 holders, who took part in the development activities. The total yield obtained was 6,599.86 quintal with average of 8.3 t/ha (Board, 2010).

The use of appropriate agronomic management has an undoubted contribution in increasing crop yield. The optimum level of agronomic practice such as plant population, planting date, harvesting date and fertilizer of the crop varies with environment, purpose of the crop and varieties. Due to the unique production nature of vegetable crops, one has to be aware on nursery, field management and post- harvest handling practices to succeed in the development effort (EARO, 2004).

Agronomic characteristics of onion

The onion root system is fibrous, spreading just beneath the soil surface to a distance of 30 to 46 cm. It has few laterals, and total root growth is sparse and not especially aggressive. Competition from aggressive root systems. (as from weed growth) severely limits onion growth (Kalb, 2001). Onion can grow in all types of soil in Ethiopia from sands loam to heavy clay, but it prefers well drained sands loam with high content of organic matter. Highest yield can be obtained from freely drained friable loam soil with PH of 6 to 6.8. Due to build up of soil born diseases, it should be rotated

with unrelated crops such as beans, and cereals. Onion could be planted at an interval of 3 to 4 years (Lemma, 2004). The best growing altitude for onion under the Ethiopian condition is between 700 to 2200 m.a.s.l and the optimum growing temperature ranges between 15 ^{0}C and 23 ^{0}C (EARO, 2004; MoARD, 2006).

Onion dry bulb can be produced throughout the year of dependable irrigation water, and diseases and insect pests control measures are available. However, the yield and quality of dry bulbs seems to vary from season to season due to diverse climatic conditions prevailing in the production areas. Findings of the research done by Melkassa agricultural research center at the upper Awash rift valley revealed that 20 cm between rows on the bed and 10 cm between plants with 333,300 plants per hectare gave high yield (150 q/ha) and was easy to manage the plant (EARO, 2004).

This is suitable for small scale hand operated production system for the Melkassa and other areas with similar agro ecologies. The spacing could be adjusted depending on the availability of facilities especially for tractor operated large scale production (Lemma, 2004).

Role of phosphorus in onion

Phosphorus size is claimed to be the second most often limiting onion plant nutrient (Tisdale *et al*; 1995) [24]. Phosphorus is essential component of the energy transfer compounds (ATP and other nucleic proteins), the genetic information system, cell membranes and phosphoproteins (Bsawas and Mukherge, 1993) [10].

Among the significant functions and qualities of onion on which phosphorus has an important effects as enhancing many aspects of onion plant physiology, including the fundamental processes of photosynthesis, reproduction, nitrogen fixation, flowering, fruiting (including seed production) and maturation. Root growth, particularly development of lateral roots and fibrous is extremely important as a structural part of many components, notably nucleic acid and phospholipids (Brady and Weil, 2002) [8].

Generally, many workers (Vechhani and Patel, 1996, and Morgan *et al*, 2005) [25, 26] investigated the role of phosphorus in onion growth. All of them agreed that the presence of phosphorus encourages plant growth, because phosphorus is an essential element particularly, phosphorus is a major building block of DNA molecule.

Effects of phosphorus on growth of onion

Phosphorus is an essential component of nucleic acids, phospholipids, phyteen and some amino acids and absorbed phosphorus helped a direct stimulation of cellular activity in roots and leaves (Singh *et al.*, 2000) [22]. It is useful for the process of cell division and meristematic growth and the net assimilation rate of phosphorus fed plants were accelerated by their increased content and the absorbed phosphorus helped the formation of food reserves due to higher photosynthetic activity (Singh *et al*, 2000) [22].

On soils containing sub optimum levels of available phosphorus, onion crops show economic responses to the application of phosphate fertilizer (Almadini *et al*, 2000) [4]. As a result, relatively large amounts are applied in commercial practices. Some reports have suggested that adequate levels of phosphorus promote early leaf canopy growth, but may advance senescence (Vechhani and Patel, 1996; and Morgan *et al*, 2005) [25, 26].

Such responses might be expected to influence the temporal patterns of radiation interception, and there by dry matter accumulation under varying conditions of phosphorus supply (Aisha *et al*, 2007) [3]. It is also evident that addition of phosphorus affects onion plant growth parameters such as number of leaves per plant, diameter of leaves- spread of plant, and plant height (Shoheen *et al*., 2007) [20].

Table 2: The growth of onion is influence by different levels of phosphorus fertilizer.

Phosphorus (kg/ha)	Survival% of seedling	Height of the plant (cm)	Length of the largest leaf	Diameter of largest leaf (cm)	Number of leaves per plant	Spread of the plant (sq.cm)
25	92.8	62.3	52.4	1.25	7.3	490
50	92.2	63.1	53.7	1.25	2.5	422
75	98.1	72.1	60.9	1.61	7.9	591
100	92.5	70.8	60.5	1.64	7.6	577.2
C1	91.5	62.5	53.5	1.25	7.2	499.5
C2	91.2	61.6	53.8	1.22	7.1	530.2
SEM+	1.11	1.22	0.24	0.16	0.067	8.459
CDat5%	3.19	3.22	0.69	0.046	0.192	24.307

C1= Control; C2= Control spraying with distilled water Source: Singh, 2000 [22]

Abdulsalam and Hamaied (2004) [2] mentioned that increasing the rate of phosphorus fertilizer up to 92 kg/ha increased plant height and leaf number. Moreover, the result of a semi- arid region of Ethiopia indicated that irrigated onions benefited from application of 200 kg/ha phosphorus compared to unfertilized crops (Shimeles, 1997) [21].

From above table, 75 kg/ha shows significantly maximum survival percentage of seedlings, significantly maximum height of plant and significantly maximum number of leaves per plant after 80 days of transplanting. Whereas minimum survival percentage, minimum height and minimum number of leaves was recorded with control (C2, spraying with distilled water) during both the year of study (Table 2) (Singh, 2000) [22].

Treatment 75 kg/ha P2O5 produced significantly maximum diameter of the longest leaf. While the control (C1 produced the minimum diameter of the longest leaf at full growth (80 days of transplanting) during both the years of experiment. The significant maximum length of the plant was noticed when the phosphorus was applied at 75 kg/ha. This indicated that the 75 kg/ha P2O5 gave the better result for all the growth parameters (Singh, 2000) [22].

Effects of phosphorus on yield of onion

Aisha *et al*, (2007) [3] reported that application of phosphorus increased the total bulb yield of onion and also enhanced average weight bulb, bulb length and bulb diameter of onion. The effect of phosphorus application in increasing bulb yield and its characteristics could be

explained through the role of phosphorus (Singh *et al*, 2000) [22].

According to Shaheen *et al*. (2007) [20], the highest application of phosphorus (92 kg/ha phosphorus) fertilizer had a major effect on the productivity of onion plant, hence increased total bulb yield and its components.

Application of phosphorus level positively increase and significantly affect bulb length, bulb diameter, average bulb weight, bulb dry matter content, marketable yield and total bulb yield (Aster, 2009). Moreover, onion yield was highest with the application of 46kg/ha of phosphorus. They also suggested that increasing phosphorus application increased bulb weight and size (Vechhani and Patel, 1993) [25].

The highest rates of phosphorus 115 and 147 kg/ha gives better growth ad yield (Singh and Singh, 2000) [22]. Growers on the south east Georgia use a considerable amount of phosphorus fertilizers as high as 89kg/ha based on a standard fertilizer program. Significant amount of phosphorus fertilizer, particularly (NH4)2H2PO4, usually appear greener with larger tops. High phosphorus fertilizer may be warranted when onion tops are damaged such as during hailstorms, these onions may also benefit from high phosphorus fertilizer in which large tops are important (Boyhan *et al*., 2001) [6].

The advanced of phosphorus application in increasing the tonnage bulbs yield and its physical properties could be explain through the role of phosphorus which is extremely important as a structural part of many components, notably nucleic acid and phospholipids. In addition, phosphorus has an indispensable role in energy metabolism, high energy of hydrolysis of phosphate and various organic phosphate bonds being used to induce chemical reaction (Shaheen *et al*, 2007) [20].

There is maximum response of onions to phosphorus fertilization in the range 0-52 kg/ha. Depending on yield level phosphorus uptake rates in onion are estimated to be about 15-30 kg/ha. Depending on soil phosphorus status, cultivar and plant density, phosphorus application rates of up to 200 kg/ha were found to maximize onion yields and bulb weights (Vechhani and Patel, 1993) [25] and reduce storage loss of bulbs (Singh *et al*., 2000) [22]. Increased phosphorus levels are also known to improve bulb size and the number of marketable bulbs in onion. Regardless of the phosphorus status of the soil, placement of phosphorus fertilizers in the soil near to the plant would be the most effective method of phosphorus supply to onion plants (Brewster, 1994) [9].

Table 3: The yield of onion influenced by different level of phosphorus fertilizer.

Phosphorus Kg/ha	Diameter of the bulb (cm)	Vertical thickness of the bulb	Weight of the bulb(gm)	Weight of the bulb per plot(gm)	Length of longest root(cm)	Number of root per plant	Yield of bulb(q/ha)
25	4.9	5.0	48.06	970.9	4.36	36.8	232.2
50	5.1	5.2	50.69	1015.6	4.66	35.4	211.6
75	6.0	6.1	61.56	1227.9	5.64	40.0	255.8
100	5.4	5.5	60.06	1178.6	4.93	41.9	254.7
C1	4.8	4.9	49.00	980.0	4.33	37.7	204.1
C2	4.5	4.5	45.00	900.0	4.23	37.5	194.8
SEM+	0.10	0.10	1.06	19.39	0.11	1.11	4.06
CDat 5%	0.30	0.28	3.04	55.72	0.33	3.20	11.67

Source: Singh *et al*, 2000 [22]

The application of phosphorus at the rate of 75 Kg/ha gave the better results for yield and yield parameters during both the years (Table 3.). These results corroborate the findings of Singh and Kumar (1969) [22], Bottcher and Kolb (1975), Asif *et al*., (1981), Hatridge and Bennett (1980), Agrawal *et al*., (1981), Fontes *et al*., (1984), Madan and Sandhu (1985), Patil *et al*., (19996), Tandaj (1991) and Patel *et al*., (1992). The favorable effects of phosphorus in promoting yield and yield parameters might be due to the fact that the phosphorus improved the carbohydrates content of the plant and it extended root growth which ultimately increased the total yield and yield parameters (Singh *et al*., 2000) [22].

As Muluneh, (2012) reported that, phosphorus application applied resulted in highly significant (p<0.001) difference in the mean bulb diameter and bulb length of onions (Table. 4).The highest mean diameter (5.76 cm) and bulb length (4.94) were recorded in the plots that received the maximum rate of phosphorus (92 Kg/ha) which were statically similar with the obtained in application of 46Kg/ha in both cases. Statically the lowest mean bulb diameter and bulb length were recorded in the control treatment. Mangrio *et al*. (1987) and El-Rehim (2000) agreed that, effects of phosphorus on the mean bulb diameter and length of onion may be through its influence on bulb development of onion plants. Similarly, Mangio *et al*., (1987) reported that, application of P at 100 Kg/ha gave wider bulb diameter.

Table 4: The main effects of phosphorus on onion yield parameter.

Treatments (P Kg/ha)	Bulb length (cm)	Bulb diameter (cm)	Mean bulb weight (g)
0	5.43b	4.59b	42.86b
46	5.55a	4.81ab	45.61a
92	5.76a	4.94a	47.52a
LSD (0.05)	0.268	0.233	2.069
CV (%)	8.89	9.01	8.45

Means in a column followed by the same letter(s) are not significantly different at 5%.
Source: Muluneh, 2012

Availability and uptakes of phosphorus by onion

Onions absorb phosphorus in the form of HPO4 and H2PO4. The physical and chemical properties of soil were reported to influence the solubility of phosphorus and its absorption reactions in soils. These include the nature and amount of the soil minerals, Soil PH, cations effect and anion effect, extent of phosphorus saturation, reaction time and temperature, flooding and fertilizer management (Tisdale *et al*, 1995) [24].

The energy stored in those phosphate compounds allow for the transportation of nutrient a cross the cell wall and the synthesis of nucleic acid and proteins (Singh *et al*, 2000) [22].

- The addition of phosphorus fertilizer ensures that crops will reach their full potential by using additional phosphorus, to encourage root growth and promoting resistances to root diseases (Brady and Well, 2002) [8].

To optimize phosphorus availability through phosphorus addition, many factors must be considered. Because of the immobility of phosphorus in most soils, the timing of fertilizer phosphorus application is less critical than placement. Even though, small amounts of placed starter fertilizer for vegetable crops have successfully reduced the need for much larger broad cast applications of phosphorus (Castigan, 1988). Several additional factors influence phosphorus availability. These include temperature, compaction, moisture aeration, PH, type and amount of nutrient (including phosphorus) status of soil (Sumner *et al*., 1986).

Summary and Conclusion

Generally, onion (*Allium cepa* L.) is one of the main crop season vegetable crops that are largely grown for different purposes like daily human diet, as salads and for preparation of various dishes like soups, sauces and seasoning of food. The production of onion varies from year to year and becomes decreasing. In farmers field its yield ranges between 9-15 t/ha which was much less than the yield obtained under research which was 30-35 t/ha (Lemma and Shimeles, 2003) [18]. The main problem for these is lack of optimum level of fertilizer mainly phosphorus fertilizer. Different authors stated different levels of phosphorus application. But, up to know there is no optimum level of phosphorus application which optimizes the production of onion.

Neither plants nor animals can grow without phosphorus. It is an essential component of the organic compound often called the energy currency of the living cell, adenosine tri-phosphate (ATP). Synthesized through both respiration and photosynthesis, ATP contains a high – energy phosphate group that drives most energy- requiring biochemical processes. The uptake of nutrients and their transport within the plant, as well as their assimilation in to different bio-molecules are energy – using plant process that requires ATP (Sopher and Baird, 1982). Phosphorus fertilizer is one the most complex in production in many tropical soil, owing to low native content and high phosphorus immobilization with in the soil. Phosphorus is essential for root development. When availability is limited, plant growth is usually reduced. In onion, phosphorus deficiencies reduced root and leaf growth, bulb size and yield and also day maturation.

In the soils that are moderately low in phosphorus, onion growth and yield can be enhanced by applying phosphorus. Onions are more susceptible to nutrient deficiencies than most crop plants because of their shallow and un-branched root system; hence they require and often respond well to addition of fertilizer.

Prospects

To optimize phosphorus availability through phosphorus addition, many factors should be considered. Because of the immobility of phosphorus in most soil, these factors are: timing and placement of phosphorus fertilizer, temperature of the soil, compaction, moisture, aeration, PH, type and amount of nutrient (including phosphorus) status of the soil.

Adoption of resistant varieties should be assured for the optimum yield of onion. Soil test should be considered for the availability of phosphorus in the soil. Research should be focused on the rate of phosphorus on growth and yield of onion. Appropriate agronomic practices should be practiced.

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