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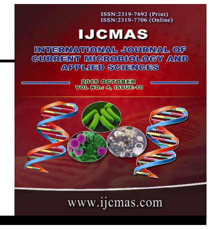

Original Research Article

Integrated use of Farmyard Manure and Inorganic Nitrogen Fertilizer on Growth, Yield and Quality of Potato (*Solanum tuberosum L.*)

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A B S T R A C T

Two field experiments were conducted during the two successive winter seasons of 2010 and 2011 at the experimental station of the Agriculture Research Centre (ARC), Kafr El-Zayat, El-Gharbia Governorate, Egypt to study the response of potato plant (*Solanum tuberosum L.*) cv Valor to application of farmyard manure as organic nitrogen fertilizer as well as ammonium nitrate (33.5% N) and urea (46%N) as inorganic nitrogen fertilizer alone or in combination on vegetative growth, yield and tubers quality of potato plants as well as nutritional content of tubers. The experiment included 18 treatments representing the interaction of farmyard manure at three levels (0, 10 and 20 m^3/fed.), ammonium nitrate and urea at three levels (120, 165 and 210 N unit/fed.). Results showed that application of farmyard manure had positively influence on vegetative growth characters of potato plants. Whereas, they were improved with increasing of farmyard manure levels up to 20 m^3/fed.; feddan (fed.) = 4200m^2 in both seasons. Vegetative growth characters of plants were enhanced by using of inorganic nitrogen fertilizer in the form of ammonium nitrate rather than urea fertilizer. Moreover, vegetative growth characters of potato plants were significantly increased with increasing of inorganic nitrogen fertilizer levels up to 210 N unit/fed. in both experimental seasons. Application of farmyard manure improved the productivity of potato plants and it was increased with increasing of farmyard manure levels up to 20 m^3/fed. in both seasons. Yield of potato plants was better with using of ammonium nitrate as inorganic nitrogen fertilizer rather than using of urea fertilizer. Furthermore, productivity of potato plants was gradually increased with increasing of inorganic nitrogen fertilizer levels. Tubers quality in response of specific gravity, starch percentage, crude protein percentage and dry matter percentage were enhanced with increasing of farmyard manure levels. On the other hand, specific gravity, starch percentage and dry matter percentage were decreased with increasing of inorganic nitrogen fertilizer levels. Yield of plants, tubers quality and nutritional content of tubers were influenced by the integration treatments between different levels of farmyard manure and different levels and forms of inorganic nitrogen fertilizer. Whereas, the highest values of tubers yield (ton/fed.), tubers number/plant, marketable tubers percentage and crude protein percentage were recorded with using of farmyard manure at the level of 20 m^3/fed. combined with inorganic nitrogen fertilizer as ammonium nitrate at the level of 210 N unit/fed. in both seasons while the highest values of specific gravity, starch percentage and dry matter percentage were observed with application of farmyard manure at the level of 20 m^3/fed. along with ammonium nitrate at the level of 120 N unit/fed. in both seasons.

K e y w o r d s

Potato, Farmyard manure levels, Inorganic nitrogen fertilizer forms, Inorganic nitrogen fertilizer levels, Vegetative growth characters, Yield, Tubers quality, Nutritional content

Introduction

Potato (*Solanum tuberosum L.*) is the fourth important crop in the world after rice, wheat and maize in terms of the human consumption. It is a global food crop. It is known as a favorite crop and regarded as one of the most important vegetable crops as human food. It is a staple food crop such as rice, wheat and tomato for the Egyptians life. In Egypt, it grows under different environmental conditions (Ahmed 1994, 1999). It is recognized as one of the most important vegetable crops for local consumption and exportation.

It is cheap source of energy, it contains high levels of carbohydrates and considerable amounts of vitamins B, C and minerals (Stephen, 1999; Tigoni, 2005; Muthoni and Nyamango, 2009).

It is relatively considered rich in some free amino acids (Smith, 1968). It contains fiber and very small amounts of fat that does not exceed milligrams (Watt and Marrill, 1963).

In Egypt, potato plays an important economic role as a food and a cash crop by potato exportation to other countries (Ahmed, 1999; Pervez *et al.*, 2000).

Both yield and tubers quality are affected by variety, environmental conditions and cultural practices. Fertilizer application has important effects on the yield and quality of potatoes (Westermann, 2005). Potato is highly responded to N fertilizer and it is usually the most specific essential nutrient for potato plant growth on all soils, especially on sandy soils (Errebhi *et al.*, 1998). The nitrogen is a vital nutrient for the activity of plant organs. It is important for many components such as amino acids, nucleic acids and leaf chlorophyll content (Najm *et al.*, 2012a). Previous studies have shown that nitrogen fertilizer can increase the growth characteristics, such as plant height, shoot dry matter, leaf area index and tubers yield (Kumar *et al.*, 2007; Sincik *et al.*, 2008; Zelalem *et al.*, 2009). Appropriate use of nitrogen fertilizer can lead to accomplishment of optimum foliage development and subsequently increases tubers yield. The excessive use of nitrogen can lead to increase vegetative growth rather than tubers production and delay potato maturity (Love *et al.*, 2005; Kumar *et al.*, 2007) and reduces tubers quality (Zebarth and Rosen, 2007). Likewise, Ahmed *et al.* (2009) indicated that vegetative growth characters, tubers yield, marketable tubers percentage and tubers quality were influenced by different rates of nitrogen fertilizer.

The conventional use of chemical fertilizer can increase the tubers yield but inordinate use of nitrogen has a negative effects on tubers quality, environment pollution, public health and economical losses (Wang *et al.*, 2002; Alva, 2004; Goffart *et al.*, 2008; Sharifi *et al.*, 2009; Najm *et al.*, 2011, 2012b), reduces starch dry matter and sugar contents in tubers and potatoes go bad more rapidly during the storage (Balemi, 2012).

In general, intensive potato cultivation requires an adequate supply of nutrients especially N element to obtain high yield and good quality. Nitrogen sources are various, plants take available N from either the soil through mineralization or the external supply of nitrogen fertilizer. Generally, nitrogen fertilizer sources are several and the common sources of its and available in Egypt are ammonium nitrate (33.5% N), ammonium sulphate (20.6%N) and urea (46% N). Several studies had been investigated the effect of different N fertilizer forms on the growth, yield and tubers quality. Despite N fertilizer sources are NO_3, $CO(NH_2)_2$ and NH_4, plants only take up N as either NO_3-N or NH_4-N (Westermann, 1993). Nitrogen applied as $CO(NH_2)_2$ to the soil, it is converted into NH_4-N by enzyme urease to become the N obtainable for plant absorption (Benson and Barnette, 1939). Karadogan (1995) indicated that the greatest growth of potato plants resulted by application N as NO_3-N followed by $NO_3 + NH_4$ and least with NH_4-N.

On the other hand, Westermann and Sojka (1996) showed that vegetative growth characters were higher by application of $(NH_4)_2SO_4$ rather than NH_4NO_3.

Moreover, Soliman *et al. (*2000) indicated that ammonium sulphate was superior in its impact on vegetative growth and yield of potato plants compared to other sources of nitrogen fertilizer such as ammonium nitrate or urea. Meanwhile, Shaheen *et al.* (1989) reported that both urea and ammonium sources had similar effects on potato tubers yield and potato specific gravity. Ahmed *et al.* (2009) demonstrated that ammonium nitrate was superior in its effect on vegetative growth, tubers yield, marketable tubers percentage and tubers quality compared to ammonium sulphate and urea.

Despite the negative effects of excessive chemical N fertilizer, application of chemical nitrogen fertilizer has remarkably increased during the last years (Freire and Sa, 2006). So, the development of new methods become an urgent need for potato producers to use other nutrient sources (Al-Moshileh and Motawei, 2005; Goffart *et al.*, 2008).

Today, the price of mineral fertilization has been raised so much in Egypt. It becomes more than the ability of the majority of framers. Besides, the high price of mineral fertilization increases the production costs.

Using of chemical fertilizers alone may not be sufficient under intensive agricultural management and result in a possible depletion of essential micronutrients thereby resulting in an overall reduction in total crop productivity (Hepperly *et al.*, 2009) and significant soil problems such as soil degradation and soil pollution causes by high application rates of chemical fertilizers (Singh, 2000).

The animal manure such as cattle manure is another source of N and other nutrients, which can decease the demand of chemical fertilizer and it has been used for many centuries to increase soil fertility (Kolay, 2007; White *et al.*, 2007; Mir and Quadri, 2009; Darzi, 2012). Except for the supply of nitrogen fraction, animal manure can improve chemical, physical and biological characteristics of the soil (Benke *et al.*, 2008; Darzi and Haj Seyed Hadi, 2012; Najm *et al.*, 2012a).

Organic fertilizer has beneficial effects including the increases of hydraulic conductivity, raises the water holding capacity, changes the soil pH where increases or decreases in the pH, depending on the soil type and characteristics of organic fertilizer, elevates the soil aggregation and water infiltration and reduces the frequency of plant diseases (Olson and Papworth, 2006; Tagoe *et al.*, 2008).

Using of animal manure such as cattle manure has positively beneficial effects on vegetative growth, yield and tuber quality (Kolay, 2007; White *et al.*, 2007; Najm *et al.*, 2010; Balemi *et al.*, 2012; Najm *et al.*, 2013).

Therefore, the present study aims to study the response of potato plants to the farmyard manure as organic fertilizer and different nitrogen forms and levels such as ammonium nitrate and urea as inorganic nitrogen fertilizers and their combination to determine the most appropriate integration for nitrogen as organic or inorganic fertilizer at different forms and levels for improving vegetative growth, obtaining the optimum potato yield and good tubers quality.

Materials and Methods

Two field experiments were carried out during the two successive winter seasons of 2010 and 2011, respectively in clay loam soil at the Agriculture Research Centre (ARC) at Kafr El-Zayat, El-Gharbia Governorate Egypt. The physical and chemical analysis of the experimental soil is shown in table 1. Farmyard manure was analyzed before using it and its entire levels were applied before cultivation of potato seed tubers (Table 2). Each experiment contained 18 treatments, which were the simple combination between 3 levels of farmyard manure i.e., 0, 10 and 20 m^3/fed., two inorganic nitrogen fertilizer forms i.e., urea (46% N) and ammonium nitrate (33.5% N) and three nitrogen fertilizer levels i.e., 120, 165 and 210 N unit/ fed. The experimental design used in the two successive winter seasons was split design with three replicates. Whereas, the three farmyard manure levels were arranged in the main plots while the two inorganic nitrogen fertilizer forms were randomly distributed in sub-plots and the three nitrogen fertilizer levels were randomly assigned in sub sub-plots. Each sub sub-plot area was 14.0m^2 consisted of three ridges each was 0.75m in width and 6.25 m long. Seed tubers cv Valor were cultivated on one side at 25 cm a part. Potato seed tubers were cultivated on 7^{th} of October and 9^{th} in the 2010 and 2011, respectively. Harvest date was done at 110 days after cultivation in both experimental seasons. The inorganic nitrogen fertilizers, urea (46%N) and ammonium nitrate (33.5% N) were divided into 2 equal doses and applied at 30 and 60 days after cultivation. The normal agricultural practices took place whenever it was necessary according to the recommendations of Egyptian Ministry of Agriculture. Six plants were taken randomly from each sub sub-plot as a representative sample at 105 day after cultivation of seed tubers and the following characters were recorded:

Vegetative growth characters

Plant length (cm), stems number/plant and leaves number/plant. Leaf area/plant (cm^2) was measured according to the method as described by Moursi *et al.* (1968). Moreover, total chlorophyll content of leaves was measured after 65 days from cultivation of seed tubers, samples of the fourth leaf were taken for determination of total chlorophyll content according to Moran and Porath (1982). Leaves and shoots fresh weights (g), whole plant fresh weight (g), leaves and shoots dry weights (g) and whole plant dry weight (g).

Tubers yield

Tubers number/plant, yield/plant (g), total tubers yield (ton/fed.) and marketable tubers percentage.

Tubers quality

Specific gravity of the potato tubers was determined using the method described by Dinesh *et al.* (2005):

$$\text{Specific gravity} = \frac{\text{Weight of tubers in air}}{\text{Weight of tubers in air - Weight of tubers under water}}$$

Starch percentage was calculated according to the method as described by Burton

(1948). Crude protein was calculated according to the following equation: Crude protein = Total nitrogen x 6.25 (A.O.A.C., 1990).

Tuber chemical content

N, P and K were determined as percentage on basis of dry weight. Nitrogen, phosphorus and potassium were determined as described by Black (1983), Troug and Mayer (1939) and Jackson (1967). Dry matter percentage was calculated according to the method as described by Burton (1948).

Results and Discussion

Vegetative growth characters

Effect of different farmyard manure levels

Data of table 3 demonstrated that application of farmyard manure had positively influence on vegetative growth characters of potato plants. Whereas, plant length, stems number/plant, leaves number/ plant, leaf area/plant, leaf chlorophyll content, leaves fresh weight, shoots fresh weight, whole plant fresh weight, leaves dry weight, shoots dry weight and whole plant dry weight were increased with increasing of farmyard manure levels up to 20 m^3/fed. in both seasons. The highest values of the above mentioned plant growth characters were obtained with the highest level of farmyard manure (20 m^3/fed.). On the other hand, the lowest values were noticed with the corresponding untreated plants. These results held good in both seasons. The statistical analysis of the obtained data revealed significant differences within different farmyard manure levels.

Improvement of vegetative growth characters of potato plants as a result of application of farmyard manure may be attributed to farmyard manure had nitrogen content and thus theses characters increased by the application of farmyard manure. In addition, farmyard manure contains other nutrients which are essential for plant growth and their tissues. The lack of tissues content of nutrients limits their potential growth. Therefore, farmyard manure plays a consequential role in increasing these characters by supplying nitrogen and a fraction of other nutrients. Also, farmyard manure improves the solubility of some elements (Clemente *et al.*, 2007; Kolay, 2007; White *et al.*, 2007). Previous studies have shown that organic fertilizers such as cattle manure, contains large amount of nutrients and influences plant growth and production via improving chemical, physical and biological fertility (Ahmed and Quadri, 2009; Benke *et al.*, 2008; Fuleky and Benedek, 2010).

The obtained results are in agreement with those reported by (Kolay, 2007; Najm *et al.*, 2010, 2013; Shaheen *et al.*, 2014).

Effect of different inorganic nitrogen fertilizer forms

Data of table 4 indicated that vegetative growth characters of potato plants were influenced by inorganic nitrogen fertilizer forms. Whereas, application of inorganic nitrogen fertilizer in the form of ammonium nitrate stimulated vegetative growth characters rather than inorganic nitrogen fertilizer in the form of urea. These findings were true in both seasons. The statistical analysis of the obtained data was great enough to reach 5% level of significance.

The vigor of vegetative growth of plants obtained with application of ammonium nitrate (33.5% N) rather than urea (46% N) as inorganic nitrogen fertilizers may be attributed to plants take up N as either NO_3-

N or NH_4-N.They prefer NO_3-N followed by NO_3+NH_4 and least with NH_4-N (Westermann, 1993). In addition, urea contains neither NO_3-N nor NH_4-N. Nitrogen applied as $CO(NH_2)_2$ is converted into NH_4-N by the enzyme urease. These series of reactions take some days before N element is favorable for plant absorption and these days may be lengthen or shorten based on several factors such as soil moisture, soil texture, soil temperature and soil organic matter (Benson and Barnette,1939).

These results are confirmed by Karadogan (1995). Who indicated that the greatest growth of potato plants resulted from supplying N as NO_3-N followed by NO_3+H_4 then with NH_4-N. Moreover, Baker *et al.* (1980) found that applying N fertilizer in the form of ammonium nitrate gave the most vigor of vegetative growth of potato plants. Meanwhile, using of ammonium sulphate resulted in weak plants (Dabis *et al.*, 1986). Superiority of vegetative growth of plants is usually obtained from using of NO_3+NH_4-N than NH_4-N (Westermann, 1993; Karadogan, 1995). Also, Ahmed *et al.* (2009) demonstrated that preeminence of vegetative growth characters of potato plants fertilized with $NH_4.NO_3$ (33.5% N) followed by $CO(NH_2)_2$ (46% N) then $(NH_4)_2SO_4$ (20.6% N) at the same rate (230 N kg/fed.) of nitrogen fertilizers.

Effect of different inorganic nitrogen fertilizer levels

Data presented in table 5 illustrated that application of inorganic nitrogen fertilizer levels significantly affected vegetative growth characters of potato plants. Whereas, plant length, stems number/plant, leaves number/plant, leaf area/plant, leaf chlorophyll content, leaves fresh weight, shoots fresh weight, whole plant fresh weight, leaves dry weight, shoots dry weight and whole plant dry weight were gradually increased with increasing of inorganic nitrogen fertilizer levels. The highest values of the above mentioned plant growth characters were recorded with the highest inorganic nitrogen levels (210 N unit/fed.). On the other hand, the lowest values of the above mentioned findings were detected with the lowest level (120 N unit/fed.). These results were true in both experimental seasons. The statistical analysis of the obtained results revealed significant differences among different inorganic nitrogen fertilizer levels.

The superiority of vegetative growth characters of potato plants which supplied nitrogen fertilizer at the highest level might be due to an increase in plant length, stems number/plant, leaves number/plant, leaf area/plant and leaf chlorophyll content (Table 5) which in turn increased photosynthetic rate and reflected more accumulation of assimilates that caused increasing of vegetative growth characters (Mauromicale *et al.*, 2006; Ahmed *et al.*, 2009).

Previous studies have shown that nitrogen is a vital nutrient for the activity of plant organs and a major for many components such as amino acids, nucleic acid and chlorophyll (Taiz and Zeiger, 2002). Nitrogen increases leaf expansion, stem branching capacity and stimulates photosynthetic capacity (Mauromicale *et al.*, 2006). Moreover, Ahmed *et al.* (2009) indicated that vegetative growth characters of potato plants increased with increasing of nitrogen rates up to 230 kg N/fed. with all nitrogen fertilizer forms. Meanwhile, the highest nitrogen rate (280 kg N/ fed.) decreased all vegetative growth characters.

Also, Yassen *et al.* (2011) showed that nitrogen application resulted in increases in the vegetative growth parameters and the highest values of these parameters were recorded with the highest level of nitrogen fertilizer (250 kg N/fed.). Recently, Shaheen *et al.* (2014) indicated that increasing of nitrogen rates within the range between 90 up to 150 unit/fed. caused a constant gradually increase in plant growth parameters. Likewise, similar trend of results are in harmony with those reported by (Alva, 2004; White *et al.,* 2007; Sincik *et al.,* 2008; Zelalem *et al.,* 2009; Najm *et al.,* 2010, 2013; Shaheen *et al.,* 2013).

Effect of the interaction between different farmyard manure levels and different inorganic nitrogen fertilizer forms and levels

Data in table 6 showed that vegetative growth parameters of potato plants were mainly responded to the interaction treatments among different farmyard manure levels and different inorganic nitrogen fertilizer forms and levels in both seasons. Whereas, application of farmyard manure at the level of 20 m^3/fed. along with inorganic nitrogen fertilizer in the form of ammonium nitrate at the level of 210 N unit/fed. resulted in the highest values of plant length, stems number/plant, leaves number/plant, leaf area/plant, leaf chlorophyll content, leaves fresh weight, shoots fresh weight, whole plant fresh weight, leaves dry weight, shoots dry weight and whole plant dry weight. On the other hand, the lowest values of the above mentioned findings were recorded with the application of inorganic nitrogen fertilizer in the form of urea at the level of 120 N unit/fed. without application of farmyard manure. These findings were true in both seasons. The statistical analysis of the obtained data revealed that no significant differences within the above interaction treatments on the vegetative growth characters except for leaves fresh weight and whole plant fresh weight in both seasons.

The observed improvement in vegetative growth characters as a results of combined effect of different farmyard manure levels and different inorganic nitrogen fertilizer forms and levels could be attributed to the combined beneficial effects for both farmyard manure at different levels and inorganic nitrogen fertilizer at different forms and levels on the vegetative growth characters of plants (Table 3, 4 and 5).

These results are in harmony with other investigators such as (Singh *et al.,* 1999) who indicated that increment of vegetative growth of plants as a result of combining of inorganic fertilizer and organic manure may be attributed to continuous application of chemical fertilizer causes a drastic reduction in organic carbon concentration, whereas addition of farmyard manure in combination with N fertilizer helped in maintaining the original organic matter status of the soil. Moreover Warren (2004) showed that organic manure such as cow dung improved the sail pH which facilitated nutrient uptake by the plant.

Also, Kingery *et al.* (1993) indicated that application of organic manure over many years had an average surface soil pH of 6.3 compared to fields receiving only chemical fertilizer (pH 5.8). Recently, Suh *et al.* (2015) in demonstrated that the highest values of plant height, stem diameter and leaf size were detected with plants which were fertilized with cow dung at the rate of 20t/ha. and NPK at the rate of (20: 10: 10) compared with sole application of cow dung or NPK mineral fertilizer Inorganic fertilizers reduce the soil pH, organic manure such as cow dung increased the organic carbon, organic matter and exchangeable cations in the soil. Organic manure ameliorates physical properties of the soil.

Yield and quality

Effect of different farmyard manure levels

Data presented in table 7 demonstrated that application of farmyard manure improved the productivity of potato plants. Whereas, yield of potato plants was significantly increased with increasing of different farmyard manure levels up to 20 m^3/fed. in both seasons. Observed increment in the productivity of potato plants reflected on the total tubers yield as ton/fed. in both seasons. The highest values of the total tubers yield were recorded with the highest farmyard manure level (20 m^3/fed.). It was 11.790 and 12.073 ton/fed. in the first and second seasons, respectively. On the other hand, the lowest values were detected with the corresponding untreated plants with farmyard manure which it was 9.479 and 9.748 ton/fed. in the first and second seasons, respectively. The differences within the different farmyard manure levels were significant at 5% level for both seasons.

With regard to tubers number/plant and marketable tubers percentage were significantly affected by different farmyard manure levels and showed the same trend of yield as mentioned before.

Regarding the tubers quality as expressed as specific gravity, starch percentage, crude protein percentage and dry matter percentage showed positively responses to the different farmyard manure levels where the highest values of them were noticed with the highest farmyard manure level (20 m^3/fed.) while the lowest values were recorded with the corresponding untreated plants with farmyard manure. The above mentioned findings were true and significant in both experimental seasons. Likewise, N, P and K contents in the tubers were increased with increasing of different farmyard manure levels in both seasons.

Enhancement of tubers yield of potato plants as a results of using of farmyard manure at different levels may be attributed to the positive effects of farmyard manure application on the vegetative growth characters of potato plants (Table 3) which consequently increased photosynthesis efficiency and synthesis of carbohydrates such as starch content which reflected on increasing of tubers yield of plants (Mauromicale *et al.,* 2006; Ahmed *et al.,* 2009).

In addition, farmyard manure is another source of nitrogen and other nutrients which it has been used for increasing soil fertility (Kolay, 2007; White *et al.,* 2007; Mir and Quadri, 2009; Darzi, 2012), It can improve chemical, physical and biological characteristics of soil (Benke *et al.,* 2008; Darzi and Haj Seyed Hadi, 2012; Najm *et al.,* 2012a), probably increases available P, mineralized N and improved cations exchange capacity of the soil (Tirol-Padre *et al.,* 2007), increases of hydraulic conductivity, raising the water holding capacity, changing the soil pH (decrease or increase in the pH, depending on soil type, elevating the soil aggregation and water infiltration, reducing the frequency of plant diseases (Conn and Lazarovits, 1999; Olson and Papworth, 2006; Tagoe *et al.,* 2008).

These results are in harmony with those reported by (Bayu *et al.,* 2006; Kolay, 2007; Najm *et al.,* 2010; Balemi, 2012; Najm *et al.,* 2013).

Effect of different inorganic nitrogen fertilizer forms

Data in table 8 indicated that productivity of potato plants was significantly affected by different forms of inorganic nitrogen fertilizer. Whereas, it was enhanced with application of inorganic nitrogen fertilizer in the form of ammonium nitrate rather than application of inorganic nitrogen fertilizer as urea in both seasons. It was 11.374 and 11.588 ton/fed. in the first and second seasons, respectively for ammonium nitrate fertilizer and it was 9.979 and 10.301 ton/fed. in the first and second seasons, respectively for urea fertilizer. Significant differences were detected among different forms of inorganic nitrogen fertilizer. These findings were true in both seasons. Concerning, tubers number/ plant and marketable tubers percentage were slightly increased with the application of ammonium nitrate rather than urea application in both seasons.

Likewise, tubers quality in terms of specific gravity, starch percentage, crude protein percentage and dry matter percentage were also enhanced by using of ammonium nitrate rather than application of urea fertilizer.

These finding were true in both experimental seasons. Statistical analysis of the obtained data failed to reach the significant level of 5% in both seasons.

Moreover, N, P and K contents in the tubers were also enhanced with the application of ammonium nitrate fertilizer rather than using of urea fertilizer. The above mentioned findings were not significant at 5% level in both seasons. The observed improvement in the total tubers yield and tubers quality with using of ammonium nitrate rather than urea as inorganic N fertilizer may be attributed to the higher positive effect of ammonium nitrate as source for N fertilizer on vegetative growth of plants rather than urea fertilizer (Table 4) which reflected on the productivity of plants and tubers quality.

In addition, plants only take up N as either NO_3-N or NH_4N (Westermann, 1993). Nitrogen applied as urea is converted into NH_4-N by enzyme urease. This is process, reaching a rate up to 90% conversion within 4 days of application at soil temperature of 21°C (Benson and Barnette, 1939).

Moreover, Polizotto *et al.* (1975), testing Red Pontiac and PU66-142 potato cultivars in solution cultures, found that growth of tops, roots and tubers was greatest with N applied as NO_3, intermediate with NH_4+NO_3 and least with NH_4 for both cultivars. Dabis *et al.* (1986) found similar findings for cv. Russet Burbank potatoes. Changing the N source from NO_3 or NH_4+NO_3 to NH_4 reduced both shoots and roots growth while changing the N source from NH_4 to NH_4 + NO_3 improved growth. They also concluded that some NO_3-N should be available to potato plants for proper growth, development and yield when NH_4-N was the sole form of N available to the plant, it was detrimental to potato growth, regardless of stage development. Moreover, Ahmed *et al.* (2009) found that NH_4NO_3 was superior in its effects on tubers yield of potato plants and tubers quality such as specific gravity, starch percentage and protein percentage as well as nutritional elements such as N, P, K and dry matter percentage followed by $CO(NH_2)_2$ then $(NH_4)_2SO_4$ in both seasons.

Effect of different inorganic nitrogen fertilizer levels

Data in table 9 showed that productivity of potato plants was significantly affected by application of different inorganic nitrogen fertilizer levels. Whereas, yield of potato plants was increased with increasing of different inorganic nitrogen levels which in turn reflected on the total tubers yield as (ton/fed.) in both seasons.

The highest values of the total tubers yield as (ton/fed.) were observed with the highest inorganic nitrogen level which it was 11.970 and 12.226 ton/fed. in the first and second seasons, respectively. On the other hand, the lowest values were recorded with the lowest inorganic nitrogen level which it was 9.480 and 9.577 ton/fed. in the first and second seasons, respectively.

Likewise, tubers number/plant and marketable tubers percentage were also influenced by different inorganic nitrogen levels and showed the same trend of yield as mentioned previously.

Concerning the tubers quality with respect to specific gravity, it is regarded an important quality character, particularly for chips and making industries. It was decreased with increasing of different inorganic nitrogen levels in both seasons. The highest specific gravity was recorded with the lowest inorganic nitrogen level (120 N unit/ fed.) and the lowest value was noticed with the highest inorganic nitrogen level (210 N unit/fed.).

Moreover, starch percentage in potato tubers was also affected by different inorganic nitrogen levels and showed the same trend of specific gravity as mentioned before.

With regard to crude protein percentage in potato tubers, it was significantly influenced by different inorganic nitrogen levels. Whereas, it was increased with increase of different inorganic nitrogen levels. The highest value was observed with the highest inorganic nitrogen fertilizer level (210 N unit/fed.). On the other hand, the lowest value was noticed with the lowest level of inorganic nitrogen fertilizer (120 N unit/fed.).

Similarly, N content in potato tubers was also affected by different inorganic nitrogen levels and showed the same trend of crude protein percentage as mentioned previously. Meanwhile, P, K and dry matter percentage in the tubers were slightly decreased with increasing of different inorganic nitrogen levels. These results were true in both experimental seasons.

Preeminence of potato yield as (ton/fed.) as a result of application of inorganic nitrogen fertilizer at different levels especially at the highest level in the present study may be attributed to the promotive effects of N element on the vegetative growth characters which they were increased with increasing of nitrogen fertilizer levels up to 210 N (unit/fed.) (Table 5) which in turn reflected on increasing of both photosynthesis efficiency and synthesis of more carbohydrates which in turn led to increasing of tubers number/plant and tubers yield/plant which consequently reflected on the total tubers yield as (ton/fed.) for all plants.

These results are confirmed with (Marguerit *et al.*, 2006) who mentioned that increasing of nitrogen fertilizer up to the suitable level increased tubers yield per unit area.

Moreover, Goffart *et al.* (2008) indicated that low N supply not only reduced leaf area but also increased early defoliation which in turn reduced both tubers size and yield. Also, Kumar *et al.* (2007) showed that higher N fertilization rates have positive effect on plant growth parameters and increased tubers number and yield. Higher N rates are associated with more foliage and subsequently promote photosynthetic action and hence more translocation to tubers.

Besides, Mauromical *et al.* (2006) indicated that nitrogen increased leaf expansion and stem branching capacity. Also Sincik *et al.* (2008) found that increasing of nitrogen fertilizer concentrations up to an optimal level increased plant height, shoot dry matter and LAI and subsequently the total crop yield.

Likewise, Ahmed *et al.* (2009) indicated that increasing of N fertilizer rates up to 230 kg N/fed. increased tubers number/plant, tubers yield/plant and total tubers yield (ton/fed.) as well as marketable tubers percentage. Meanwhile, nitrogen fertilizer at the rate of 280 kg N/fed. decreased the yield of plants.

Recently, Shaheen *et al.* (2014) reported that increasing of nitrogen rates up to 150 N unit/fed. caused a constant gradually increase in the yield of plants.

Similar results are detected by other investigators such as (White *et al.*, 2007; Zelalem *et al.*, 2009; Shahzd Jamatti *et al.*, 2010; Yassen *et al.*, 2011; Ruza *et al.*, 2013; Shaheen *et al.*, 2013).

Regarding the tubers quality such as specific gravity and starch percentage as well as dry matter percentage in potato tubers, decreasing of specific gravity, starch percentage and dry matter percentage in potato tubers with increasing of different inorganic N fertilizer levels especially at the highest level might be due to the excessive use of nitrogen fertilizer led to reduction of specific gravity, starch percentage and dry matter percentage of potato tubers. Whereas, specific gravity is positively associated with starch content in the tubers. Starch is the main component for dry matter in the tubers. Therefore, dry matter content in the tubers is also associated with specific gravity of tubers (Nylund, 1966). So, increasing of inorganic N fertilizer levels up to 210 N unit/fed. led to decreasing of specific gravity and starch percentage as well as dry matter percentage of potato tubers.

Similar trend of results are confirmed by Ahmed *et al.* (2009) who indicated that increasing of different inorganic nitrogen fertilizer levels up to 280 kg N/fed. decreased specific gravity and starch percentage of tubers as well as dry matter percentage in potato tubers. The highest levels of them were found with the lowest nitrogen level (130 kg N/fed.) while the lowest levels were recorded with the highest nitrogen level (280 kg N/fed.) in both seasons. Likewise Ruza *et al.* (2013) demonstrated that the highest starch concentration was found in the non-fertilized treatment. With increasing of nitrogen fertilizer rate, starch concentrations in tubers decreased to 15.4% in treatment N 210 Kg/ha.

These results are also in agreement with those reported by (Haris, 1992; Zelalem *et al.*, 2009; Yassen *et al.*, 2011; Balemi *et al.*, 2012).

Concerning N content and crude protein percentage in the tubers, increasing of nitrogen content in the tubers and crude protein percentage as a result of increasing of inorganic N fertilizer levels may be attributed to the positive effects of nitrogen on both N content and crude protein percentage in the tubers. Whereas, nitrogen is a major component of protein. Nitrogen is a vital role in plant that associated directly and indirectly with protein synthesis and it was significantly increased with increasing of nitrogen doses (Erdogan *et al.*, 2010).

These results are also confirmed with other investigators such as Ahmed *et al.* (2009) who indicated that increasing of N fertilizer rates up to 280 kg N/fed. increased N content and protein percentage in the tubers. Meanwhile, decreased P and K contents in the tubers. Also, Yassen *et al.* (2011) showed that N content and protein percentage in the tubers were increased with increasing of nitrogen fertilizer levels up to 250 kg N/fed. Likewise, Shaheen *et al.*

(2013) indicated that using of higher rate of urea (135N unit/fed.) significantly increased N content and protein percentage in the tubers except for phosphorus and potassium percentages. Whereas, the highest values of P and K percentages were recorded with the lowest level of urea (65 N unit/fed.).

Effect of the interaction between different farmyard manure levels and different inorganic nitrogen fertilizer forms and levels

Data presented in table 10 showed that productivity of potato plants was significantly affected by the interaction treatments between different farmyard manure levels and different inorganic nitrogen fertilizer forms and levels. Whereas, the highest tubers yield was recorded with that plants which supplied with farmyard manure at the level of 20 m^3/fed. integrated with inorganic N fertilizer in the form of ammonium nitrate at the level of 210 N unit/fed. in both experimental seasons. It was 13.881 and 13.941 ton/fed. in the first and second seasons, respectively. On the other hand, the lowest tubers yield was detected with the corresponding plants which supplied with inorganic nitrogen fertilizer in the form of urea at the level of 120 N unit/fed. without application of farmyard manure. It was 7.782 and 7.772 ton/fed. in the first and second seasons, respectively. These findings were true in both experimental seasons. The statistical analysis of the obtained data was significant at 5% level in both seasons.

Likewise, tubes number/plant and marketable tubers percentage were moderately increased by the interaction treatments and showed the same tubers yield as mentioned previously.

Regarding, tubers quality as expressed as specific gravity and starch percentage of potato tubers were decreased by the different interaction treatments. Whereas, the highest values of them were detected with the plants which supplied with farmyard manure at the level of 20 m^3/fed. combined with inorganic nitrogen fertilizer in the form of ammonium nitrate at the level of 120 N unit/fed. On the other hand, the lowest values were observed with that plants which supplied with inorganic nitrogen fertilizer in the form of urea at the level of 210 N unit/ fed. without application of farmyard manure.

Concerning, crude protein percentage in the tubers was also positively responded to the different interaction treatments and showed the same trend of tubers yield as mentioned previously.

With regard to, nutritional elements in terms of N content in tubers was also increased by the different interaction treatments and also showed the same trend of yield as mentioned before. Meanwhile, P, K and dry matter percentage in tubers were decreased by the different interaction treatments and showed the same trend of specific gravity and starch percentage as mentioned previously. These findings were true in both seasons. The statistical analysis of the obtained data was not significant at 5% level in both seasons. It means that each treatment act independently on tubers quality characters.

Table.1 Physical and chemical analysis of the experimental soil during the two successive seasons of 2010 and 2011

A-Physical properties	2010	2011
Soil texture	Clay loam	Clay loam
Clay (%)	47.60	48.20
Silt (%)	29.20	28.50
Fine sand (%)	21.30	21.60
Coarse sand (%)	1.90	1.70
B- Chemical analysis		
Available (k) mg/100 g soil	0.42	0.50
Available (P) mg/100 g soil	4.90	5.82
Total (N) mg/100 g soil	150.60	145.80
Cl (meq/L)	1.85	1.90
CO_3 (meq/L)	5.15	4.64
Na_2CO_3 (meq/L)	3.75	2.83
$CaCO_3$ (meq/L)	1.73	1.69
SO_4 (ppm)	80.50	95.50
Organic matter (%)	1.82	1.66
EC (mmhos/cm/25°C)	2.15	2.19
pH	8.1	8.3
Fe (ppm)	17.90	18.30
Zn (ppm)	1.10	1.15
Mn (ppm)	6.50	5.74
Cu (ppm)	4.55	3.71

Table.2 Chemical analysis of cattle manure added to the experimental soil

Parameters	Cattle manure
Ec (ds/m)	4.56
pH	9.61
N%	2.23
P%	0.35
K%	2.95
Mn ppm	456
Fe ppm	1830
Zn ppm	80
Cu ppm	63
Pb ppm	6.8
Cd ppm	2.5
C/N ratio	11:83
OM%	21.3
Moisture %	16.3

Table.3 Effect of different farmyard manure levels on the vegetative growth characters of potato plant during the two successive seasons of 2010 and 2011

FYM level (m^3/f)	Plant length (cm)	Stems No/Plant	Leaves No/plant	Leaf are/ plant (cm^2)	Leaf chlorophyll content	Leaves fresh weight/ plant (g)	Shoots fresh weight /plant (g)	Whole plant fresh weight (g)	Leaves dry weight/ plant (g)	Shoots dry weight/ plant (g)	Whole plant dry weight (g)
	First season										
0	43.4	3.6	26.4	2198.2	3.889	119.6	24.5	144.1	13.3	9.5	22.8
10	46.8	4.0	29.3	2290.2	4.512	135.3	27.5	162.8	16.4	12.6	29.0
20	50.2	4.4	31.8	2401.4	4.737	139.9	30.3	170.8	19.9	16.1	36.0
LSD at 5%	0.4	NS	0.9	12.6	0.437	1.2	0.9	1.3	0.4	0.4	0.8
	Second season										
0	44.0	3.8	26.8	2083.5	3.925	121.3	25.8	147.1	14.0	9.7	23.7
10	47.3	4.0	29.5	2196.9	4.486	136.1	28.9	165.0	16.9	12.8	29.7
20	50.8	4.5	32.1	2311.9	4.794	140.5	32.4	172.2	20.7	16.4	37.0
LSD at 5%	0.4	NS	0.8	43.7	0.126	1.2	0.4	1.3	0.4	0.4	0.8

Table.4 Effect of different inorganic nitrogen fertilizer forms on the vegetative growth characters of potato plant during the two successive seasons of 2010 and 2011

Inorganic N-forms	Plant length (cm)	Stems No/Plant	Leaves No/plant	Leaf are/ plant (cm^2)	Leaf chlorophyll content	Leaves fresh weight/ plant (g)	Shoots fresh weight /plant (g)	Whole plant fresh weight (g)	Leaves dry weight/ plant (g)	Shoots dry weight/ plant(g)	Whole plant dry weight (g)
	First season										
Urea	45.5	3.9	27.8	2276.9	4.361	129.3	26.7	156.0	16.0	12.4	28.5
Ammonium nitrate	48.1	4.1	30.6	2316.3	4.398	133.9	28.2	162.4	17.0	13.0	30.0
LSD at 5%	0.4	NS	1.5	NS	NS	1.1	1.3	1.1	0.4	0.4	0.6
	Second season										
Urea	46.0	4.0	28.3	2182.8	4.343	130.6	28.3	158.5	16.9	12.7	29.6
Ammonium nitrate	48.7	4.1	30.6	2212.0	4.460	134.7	29.8	164.4	17.4	13.3	30.6
LSD at 5%	0.4	NS	1.3	NS	NS	1.0	0.4	1.8	0.4	NS	0.6

Table.5 Effect of different inorganic nitrogen fertilizer levels on the vegetative growth characters of potato plant during the two successive seasons of 2010 and 2011

N- level (N-unit/ fed.)	Plant length (cm)	Stems No/Plant	Leaves No/plant	Leaf are/ plant (cm^2)	Leaf chlorophyll content	Leaves fresh weight/ plant (g)	Shoots fresh weight /plant	Whole plant fresh weight (g)	Leaves dry weight/ plant (g)	Shoots dry weight/ plant (g)	Whole plant dry weight (g)
	First season										
120	44.4	3.7	26.5	1772.6	4.151	118.0	24.0	142.0	15.0	11.4	26.4
165	46.4	4.0	28.8	2325.8	4.302	128.6	26.0	154.6	16.6	12.7	29.3
210	49.6	4.3	32.3	2791.4	4.687	148.2	32.3	181.1	18.1	14.1	32.1
LSD at 5%	0.8	NS	0.5	74.9	NS	0.6	1.0	1.1	0.8	0.7	0.7
	Second season										
120	44.8	3.8	26.6	1705.0	4.221	119.0	25.3	144.3	15.5	11.6	27.2
165	47.2	4.1	29.2	2193.3	4.400	129.6	27.5	156.5	17.0	12.8	29.8
210	50.1	4.4	32.6	2694.0	4.584	149.3	34.3	183.6	19.0	14.4	33.4
LSD at 5%	0.8	NS	0.6	77.7	NS	1.2	0.8	1.0	0.7	0.6	0.7

Table.6 Effect of the interaction between different farmyard manure levels and different inorganic nitrogen fertilizer forms and levels on the vegetative growth characters of potato plant during the two successive seasons of 2010 and 2011

FYM levels (m^3/f)	N-forms	N-Levels (kg N/F)	Plant length (cm)	Stems No/Plant	Leaves No/plant	Leaf area/ plant (cm^2)	Leaf chlorophyll content	Leaves fresh weight/ plant (g)	Shoots fresh weight /plant(g)	Whole plant fresh weight (g)	Leaves dry weight/ plant (g)	Shoots dry weight/ plant (g)	Whole plant dry weight (g)
	First season												
0	Urea	120	39.5	3.4	22.5	1626.3	3.523	103.2	20.5	123.7	11.4	8.1	19.5
		165	42.3	3.6	24.7	2241.4	3.713	113.8	21.7	135.5	13.2	9.3	22.5
		210	44.5	3.8	28.3	2672.4	4.481	131.3	28.2	159.5	14.1	10.2	24.3
	Ammonium nitrate	120	42.5	3.4	25.2	1692.2	3.579	106.9	21.3	128.2	12.3	8.3	20.6
		165	44.3	3.7	27.3	2273.4	3.724	117.3	23.8	141.1	13.5	9.6	23.1
		210	47.4	3.9	30.3	2683.7	4.316	145.2	31.2	176.4	15.2	11.5	26.7
10	Urea	120	43.7	3.6	24.6	1738.2	4.256	120.3	23.6	143.9	14.5	11.2	25.7
		165	45.4	3.8	27.8	2286.6	4.446	131.4	24.8	156.2	16.3	12.4	28.7

		210	47.4	4.2	31.4	2784.4	4.714	149.6	31.4	181.0	17.2	13.3	30.5
	Ammonium nitrate	120	45.6	3.7	28.3	1814.2	4.312	124.2	24.1	148.3	15.4	11.4	26.8
		165	47.2	3.9	30.4	2322.4	4.457	134.6	26.9	161.5	16.6	12.7	29.3
		210	51.3	4.5	33.4	2795.5	4.889	151.6	34.3	185.9	18.3	14.6	32.9
20	Urea	120	46.4	4.0	27.2	1849.4	4.589	124.8	26.8	151.6	17.2	14.7	31.9
		165	47.6	4.3	29.4	2397.6	4.679	135.6	28.5	164.1	19.8	15.9	35.7
		210	52.6	4.6	34.1	2895.8	4.847	154.1	34.7	188.8	20.7	16.8	37.5
	Ammonium nitrate	120	48.8	4.1	30.9	1915.3	4.645	128.7	27.5	156.2	18.9	14.9	33.8
		165	51.4	4.4	33.1	2433.5	4.790	139.1	30.3	169.4	20.1	16.2	36.3
		210	54.4	4.9	36.2	2916.7	4.872	157.3	34.1	194.7	22.8	18.1	40.9
LSD at 5%			NS	NS	NS	NS	NS	1.6	NS	2.7	NS	NS	NS
	Second season												
0	Urea	120	40.3	3.5	22.4	1561.3	3.639	104.4	21.8	126.2	12.3	8.2	20.5
		165	42.5	3.7	24.9	2076.9	3.803	114.7	23.6	138.3	13.6	9.5	23.1
		210	44.8	3.9	29.8	2575.7	4.259	135.8	29.7	165.5	15.6	10.6	26.2
	Ammonium nitrate	120	42.6	3.6	25.4	1617.5	3.664	107.6	22.5	130.1	12.6	8.6	21.2
		165	45.6	3.8	27.7	2083.6	3.831	118.3	24.7	143.0	13.8	9.7	23.5
		210	47.9	4.0	30.8	2585.9	4.354	146.9	32.5	179.4	15.8	11.7	27.5
10	Urea	120	43.8	3.7	25.7	1673.1	4.272	121.5	24.9	146.4	14.4	11.3	25.7
		165	45.6	3.9	27.9	2188.3	4.536	132.2	26.9	159.1	16.7	12.6	29.3
		210	48.5	4.3	31.9	2687.4	4.359	150.1	32.8	182.9	18.7	13.7	32.4
	Ammonium nitrate	120	45.8	3.8	27.5	1739.8	4.397	124.9	25.6	150.5	15.7	11.7	27.4
		165	48.7	4.0	30.8	2195.1	4.564	135.6	27.8	163.4	16.9	12.8	29.7
		210	51.6	4.5	32.9	2697.5	4.787	152.2	35.5	187.7	18.9	14.8	33.7
20	Urea	120	46.6	4.1	27.3	1784.3	4.625	126.2	28.1	154.3	18.9	14.8	33.7
		165	48.8	4.4	30.6	2299.5	4.769	136.5	30.2	163.4	20.2	16.1	36.3
		210	52.7	4.6	34.5	2798.7	4.730	153.6	36.6	190.2	22.1	17.2	39.3
	Ammonium nitrate	120	49.8	4.2	31.1	1853.8	4.730	129.4	28.9	158.3	19.2	15.2	34.4
		165	51.9	4.5	33.4	2316.3	4.897	140.1	31.5	171.6	20.7	16.3	37.0
		210	54.8	4.9	35.9	2818.5	4.920	156.9	38.8	195.7	22.9	18.5	41.4
LSD at 5%			NS	NS	NS	NS	NS	3.0	NS	2.4	NS	NS	NS

Table.7 Effect of different farmyard manure levels on the yield and quality as well as nutritional content of potato plant during the two successive seasons of 2010 and 2011

FYM levels (N unit/fed.)	Tubers No/plant	Yield/ plant (g)	Yield (ton/f)	Marketable tubers %	Specific gravity (g/cm^3)	Starch %	Crude protein %	N %	P %	K %	Dry matter %
	First season										
0	7.5	437.0	9.479	94.4	1.0330	4.444	14.372	2.300	0.448	2.166	10.292
10	10.2	495.9	10.761	95.5	1.0459	7.006	14.946	2.391	0.562	2.192	13.009
20	11.8	543.2	11.790	96.6	1.0522	8.272	15.880	2.485	0.594	2.252	14.350
LSD at 5%	0.8	5.3	0.122	0.8	0.0127	2.621	0.714	0.044	0.044	NS	2.779
	Second season										
0	7.6	449.2	9.748	94.8	1.0347	4.790	14.444	2.311	0.470	2.184	10.660
10	10.6	507.5	11.012	95.8	1.0448	6.865	14.879	2.381	0.587	2.200	12.882
20	12.0	556.4	12.074	96.9	1.0510	8.035	15.412	2.465	0.604	2.254	14.099
LSD at 5%	0.8	8.4	0.183	0.8	0.0093	1.804	0.008	0.073	0.050	NS	1.954

Table.8 Effect of different inorganic nitrogen fertilizer forms on the yield and quality as well as nutritional content of potato plant during the two successive seasons of 2010 and 2011

Inorganic N-forms	Tuber No/ Plant	Yield/ plant (g)	Yield (ton/f)	Marketable tubers %	Specific gravity (g/cm^3)	Starch %	Crude protein %	N %	P %	K %	Dry matter %
	First season										
Urea	9.6	459.8	9.979	95.2	1.0423	6.297	14.946	2.354	0.518	2.197	12.257
Ammonium nitrate	10.1	524.2	11.374	95.7	1.0451	6.851	15.185	2.430	0.551	2.209	12.844
LSD at 5%	NS	4.8	0.106	NS	NS	NS	NS	NS	NS	NS	NS
	Second season										
Urea	9.9	474.7	10.301	95.6	1.0421	6.263	14.802	2.368	0.550	2.208	12.221
Ammonium nitrate	10.3	534.0	11.588	96.0	1.0449	6.863	15.022	2.403	0.557	2.218	12.873
LSD at 5%	NS	2.4	0.054	NS	NS	NS	NS	NS	NS	NS	NS

Table.9 Effect of different inorganic nitrogen fertilizer levels on the yield and quality as well as nutritional content of potato plant during the two successive seasons of 2010 and 2011

N-levels (N unit/fed.)	Tubers No/plant	Yield/ plant (g)	Yield (ton/f)	Marketable tubers %	Specific gravity (g/cm^3)	Starch %	Crude protein %	N %	P %	K %	Dry matter %
	First season										
120	8.7	437.0	9.480	94.6	1.0556	8.946	14.452	2.312	0.590	2.259	15.065
165	9.6	487.5	10.580	95.1	1.0430	6.442	15.265	2.387	0.531	2.188	12.411
210	11.2	551.6	11.970	96.8	1.0324	4.333	15.480	2.477	0.482	2.162	10.175
LSD at 5%	0.9	5.8	0.130	0.7	0.0088	1.716	0.724	0.071	0.078	NS	1.820
	Second season										
120	8.9	441.3	9.577	95.3	1.0565	9.123	14.373	2.300	0.621	2.269	15.254
165	9.8	508.4	11.032	95.8	1.0421	6.334	14.900	2.384	0.558	2.198	12.319
210	11.6	563.4	12.226	96.4	1.0319	4.233	15.462	2.473	0.481	2.171	10.068
LSD at 5%	1.6	3.8	0.082	0.8	0.0055	1.093	0.486	0.078	0.075	NS	1.156

Table.10 Effect of the interaction between different farmyard manure levels and different inorganic nitrogen fertilizer forms and levels on the yield and quality as well as nutritional content of potato plant during the two successive seasons of 2010 and 2011

FYM levels (m^3/f)	N-forms	N-Levels (kg N/F)	Tubers No/plant	Yield /plant (g)	Yield (ton/f)	Marketable tubers %	Specific gravity (g/cm^3)	Starch %	Crude protein %	N %	P %	K %	Dry matter %
	Fist season												
0	Urea	120	6.4	358.6	7.782	93.1	1.0422	6.279	13.694	2.191	0.496	2.194	12.237
		165	7.2	421.4	9.145	93.6	1.0311	4.069	14.150	2.264	0.457	2.153	9.895
		210	8.2	464.1	10.071	95.6	1.0205	1.959	14.725	2.356	0.374	2.125	7.658
	Ammonium nitrate	120	6.9	382.0	8.272	93.8	1.0451	6.863	14.363	2.298	0.517	2.210	12.856
		165	7.5	453.8	9.846	94.3	1.0340	4.653	14.406	2.305	0.460	2.171	10.514
		210	8.5	542.0	11.761	95.7	1.0249	2.841	14.894	2.383	0.385	2.143	8.593
10	Urea	120	8.2	423.3	9.185	94.2	1.0544	8.707	14.213	2.274	0.578	2.221	14.812
		165	9.5	472.6	10.255	94.7	1.0455	6.929	14.875	2.380	0.538	2.183	12.927
		210	11.5	515.3	11.181	96.7	1.0341	4.666	15.056	2.409	0.485	2.156	10.528

	Ammonium nitrate	120	9.4	466.3	10.118	94.9	1.0580	9.424	14.525	2.324	0.618	2.231	15.572
		165	10.5	509.5	11.056	95.4	1.0474	7.320	15.100	2.416	0.571	2.191	13.341
		210	12.2	588.5	12.771	96.8	1.0357	4.991	15.906	2.545	0.581	2.167	10.872
20	Urea	120	10.4	443.7	9.629	95.3	1.0666	11.143	14.838	2.374	0.657	2.346	17.394
		165	11.2	479.5	10.411	95.8	1.0490	7.626	17.264	2.429	0.579	2.211	13.665
		210	13.4	560.2	12.157	97.8	1.0373	5.297	15.700	2.512	0.496	2.184	11.196
	Ammonium nitrate	120	10.6	548.1	11.894	96.0	1.0672	11.262	15.081	2.413	0.675	2.354	17.520
		165	11.4	588.3	12.766	96.5	1.0511	8.057	15.794	2.527	0.582	2.218	14.122
		210	13.6	639.7	13.881	97.9	1.0420	6.245	16.600	2.656	0.572	2.197	12.202
LSD at 5%			NS	14.3	0.318	NS	NS	NS	NS	NS	NS	NS	NS
	Second season												
0	Urea	120	6.5	358.2	7.772	94.1	1.0429	6.418	13.843	2.215	0.532	2.218	12.385
		165	7.5	431.0	9.352	94.5	1.0318	4.208	14.350	2.296	0.504	2.178	10.043
		210	8.3	472.1	10.243	95.6	1.0243	2.722	14.981	2.397	0.374	2.143	8.467
	Ammonium nitrate	120	6.9	383.8	8.328	94.3	1.0465	7.132	13.906	2.225	0.535	2.227	13.152
		165	7.7	503.1	10.918	94.8	1.0354	4.932	14.475	2.316	0.491	2.183	10.809
		210	8.7	547.2	11.874	95.6	1.0274	3.326	15.106	2.417	0.385	2.158	9.107
10	Urea	120	8.8	427.7	9.282	95.2	1.0551	8.847	14.363	2.298	0.643	2.231	14.960
		165	9.8	501.8	10.889	95.6	1.0445	6.730	14.619	2.339	0.583	2.194	12.716
		210	12.2	532.4	11.553	95.7	1.0319	4.228	15.125	2.420	0.521	2.161	10.063
	Ammonium nitrate	120	9.6	471.8	10.238	95.4	1.0590	9.616	14.613	2.338	0.647	2.238	15.776
		165	10.7	512.8	11.128	95.9	1.0446	7.214	15.181	2.429	0.595	2.199	13.370
		210	12.6	598.3	12.984	96.7	1.0335	4.553	15.375	2.460	0.531	2.177	10.408
20	Urea	120	10.6	455.8	9.892	96.3	1.0673	11.275	14.694	2.351	0.674	2.341	17.534
		165	11.4	505.3	10.966	96.7	1.0462	7.075	15.263	2.442	0.584	2.217	13.081
		210	13.7	588.1	12.761	96.8	1.0351	4.865	15.977	2.553	0.534	2.188	10.739
	Ammonium nitrate	120	10.7	550.6	11.948	96.5	1.0682	11.448	14.819	2.371	0.697	2.359	17.717
		165	11.7	596.2	12.938	97.0	1.0501	7.845	15.513	2.482	0.591	2.219	13.897
		210	13.8	642.4	13.941	97.8	1.0393	5.701	16.206	2.593	0.542	2.198	11.625
LSD at 5%			NS	9.3	0.202	NS	NS	NS	NS	NS	NS	NS	NS

Improvement of the productivity of potato plants as a result of the interaction treatments between farmyard manure and inorganic nitrogen fertilizer could be attributed to the single use of farmyard manure or inorganic nitrogen fertilizer has a positive effect on vegetative growth characters of plants but the integrated use for both farmyard manure at different levels and inorganic nitrogen fertilizer at different forms and levels has more beneficial effects on these characters which consequently reflected positively on the productivity of these plants. Whereas, there is an association between above-ground and under-ground organs of the potato plant (Struik, 2007a). So, the final tubers yield can be influenced by the situation of above-ground organs in the growing seasons (Struik, 2007b). Moreover, White *et al.* (2007) demonstrated that the increase in LAI of shoots can increase radiation absorption particularly, at the time of tubers initiation which has a positive effect on the final tubers yield.

Also, Islam *et al.* (2008) found that the combination of organic matter with conventional farming showed its superiority on yield and yield contributing parameters of potato.

Likewise, Baniuniene and Zekaite (2008) indicated that farmyard manure (FYM) increased potato tuber yield by 35-82%, depending on mineral fertilizer combination. Besides, Balemi (2012) showed that application of 20 or 30 ton/ha FYM + 66.6% of the recommended inorganic NP fertilizers significantly increased total tubers yield. In addition to, Najm *et al.* (2010, 2013) indicated that nitrogen fertilizer, cattle manure and their combination had highly significant effects on tubers yield. The maximum tubers yield (36.8 tons ha^{-1}) was obtained by the utilization of 150 kg nitrogen per hectare + 20 tons cattle manure.

Recently, Suh *et al.* (2015) observed that potato yield was increased by the combined use of animal manure such as cow dung and NPK (20 : 10 : 10) compared with sole application of cow dung or NPK mineral fertilizer.

The obtained results are also in harmony with those reported by (Bayu *et al.*, 2006; Kolay, 2007).

In conclusion, it could be concluded that using of farmyard manure as organic fertilizer at the level of 20 m^3/fed. integrated with ammonium nitrate as inorganic N fertilizer at the level of 210 N unit/fed. gave the highest values of tubers yield (ton/fed.), tubers number/plant, marketable tubers percentage, N content in the tubers and crude protein percentage of potato tubers while using of farmyard manure at the level of 20 m^3/fed. combined with ammonium nitrate at the level of 120 N unit/fed. gave the highest values of specific gravity, starch percentage, P, K and dry matter percentage in the tubers. Using of organic fertilizer is very important not only for increasing the potato yield but also for maintaining soil health. Besides, application of organic fertilizer integrated with mineral fertilizer decreases the cost of production due to the continuous increase in the prices of mineral fertilization.

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