EFFECT OF POTASSIUM CHLORIDE AND CATTLE DUNG ASH ON GROWTH, YIELD AND QUALITY OF CARROT (*Daucus carota* L.) IN DEBRE BERHAN, CENTRAL HIGHLANDS OF ETHIOPIA

MSc. Thesis

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A Thesis Submitted to the Department of Plant Sciences
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In Partial Fulfillment of the Requirements for the Degree of Master of Science in Agronomy

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Major Advisor: Bizuayehu Desta (Ph.D.)
Co-Advisor: Haymanot Awgchew (Ph.D. Candidate)

October 2021
Debre Berhan, Ethiopia

COLLEGE OF GRADUATE STUDIES
COLLEGE OF AGRICULTURE AND NATURAL RESOURCE SCIENCES
DEBRE BERHAN UNIVERSITY

APPROVAL SHEET – I

This is to certify that the thesis entitled: **Effect of Potassium Chloride and Cattle Dung Ash on Growth, Yield and Quality of Carrot (*Daucus Carota* L.) in Debre Berhan, Central Highland of Ethiopia** submitted in partial fulfillment of the requirements for the degree of Masters of Science with specialization in ***Agronomy*** of the Graduate Program of the Department of ***Plant Science***, College of Agriculture and Natural Resource Sciences, Debre Berhan University and is a record of original research carried out by **Betelhem Taye, PGR/ 214/12** under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged. Therefore, I recommend that it to be accepted as fulfilling the thesis requirements.

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APPROVAL SHEET – II

We, the undersigned members of the board of the examiners of the final open defense by **Betelhem Taye** have read and evaluated her thesis entitled: **Effect of Potassium Chloride and Cattle Dung Ash on Growth, Yield and Quality of Carrot (*Daucus Carota* L.) in Debre Berhan, Central Highland of Ethiopia,** and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Agronomy.

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Name of external examiner	Signature	Date

Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the Council of Graduate Studies (CGS) through the department graduate Committee (DGC) of the candidate's major department.

BIOGRAPHICAL SKETCH

The author was born on September 11, 1996, to her father Mr. Taye Mengesha and her mother Mrs. Tehaynesh Assefa at Dessie town South Wollo Zone, Amhara National Regional State, Ethiopia. She attended her elementary education (grades 1-6 at Debre Berhan Atse Zeryakob Elementary School from 2003-2011, Junior Secondary Education at Debre Berhan General School (grades 9-10) from 2011-2012, and Secondary Education at Hailemariam Mamo Preparatory School from 2013-2014. Then, she joined Debre Berhan University in September 2015 and graduated with BSC degree in Horticulture in 2017.

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DEDICATION

I dedicate this thesis manuscript to my beloved and esteemed family for nursing me with affection and care, and for their wholehearted partnership in the success of my life.

STATEMENT OF THE AUTHOR

I, Betelhem Taye declare that, this thesis is my genuine work, and that all sources of materials used for this thesis have been profoundly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for Master of Science (MSc.) at Debre Berhan University and it is deposited at the University library to be made available for users under the rule of the library. I intensely declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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Date of Submission: ________________________

ACRONYMS AND ABBREVATIONS

ANOVA	Analysis of Variance
CDA	Cattle Dung-cake Ash
CEC	Cation Exchange Capacity
DMRT	Duncan's Multiple Range Test
EC	Electrical Conductivity
CEC	Cation Exchange Capacity
ETB	Ethiopian's Birr
FAOSTAT	Food and Agricultural Organization Statistics
FYM	Farmyard Manure
GDP	Gross domestic product
IAR	Institute of Agricultural Research
ISSS	International Soil Science Society
KCl	Potassium Chloride
m a.s.l	Meter Above Sea Level
OC	Organic carbon
pH	Potential of Hydrogen
RCBD	Random Complete Block Design
SAS	Statistical Analysis System
TN	Total Nitrogen
TSS	Total Soluble Solids

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EFFECT OF POTASSIUM CHLORIDE AND CATTLE DUNG Ash ON GROWTH, YIELD AND QUALITY OF CARROT (*Daucus carota* L.) IN DEBRE BERHAN, CENTRAL HIGHLANDS OF ETHIOPIA

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ABSTRACT

Due to its ease of production, nutritional value, good taste, and short durational crop, carrot (*Daucus carota* L.) *is an important root vegetable in the world in general and in Ethiopia in particular. However, its yield is constrained by different yield-limiting factors including low soil fertility, type of fertilizer used and fault of its application. Most carrot growers use inorganic fertilizers with a sub-optimal amount of fertilizers containing only N and P nutrients to improve carrot yields by considering K is sufficient in the soils; hence, there is no information about crop and location-specific rate of K applications. Thus, a field experiment was carried out during the main cropping season of 2020 with the main objectives of evaluating the effect potassium-containing amendments sourced from (KCl) and [cattle dung-cake ash (CDA)] at different rates on growth, yield, and quality of carrot. The treatments consisted of factorial combinations of four levels of KCl (0, 50, 100, and 150 kg ha $^{-1}$) and four levels of CDA (0, 10, 20, 30 t ha $^{-1}$) arranged in a Randomized Complete Block Design (RCBD) with three replications. The results indicated that the combined application of 50 kg ha $^{-1}$ of KCl and 10 t ha $^{-1}$ of CDA resulted in the highest plant height (34.55cm), leaf number (13.57), root yield (22.15 t ha $^{-1}$), and the longest root length (11.44 cm) compared to the control. The combined use of KCl and CDA were non-significant ($P>0.05$) for marketable root number, marketable root yield, and total soluble solid (TSS). However, application of CDA provided significant ($P<0.05$) results on these parameters. Accordingly, the highest marketable root number (44.67), marketable root yield (1.36 kg), and TSS of (8.22) were recorded due to the application of CDA at a rate of 10 t ha^{-1}. Furthermore, the combined application of 50 kg ha $^{-1}$ of KCl and 10 t ha $^{-1}$ of CDA had resulted the highest net benefit (181,540.00 Ethiopian Birr ha $^{-1}$) with a marginal rate of return (MRR) of 958.824%. Thus, the study concluded that the combined use of KCl and CDA at a rate of 50 kg ha $^{-1}$ and 10 t ha $^{-1}$, respectively, could be more productive and economically advantageous. However, additional studies need to be conducted in the future at different locations, and seasons. In addition, different source of inorganic potassium such as K_2SO_4, KNO_3, etc. should be tested to come up with best recommendations.*

Keywords: Cattle Dung- Ash (CDA), KCl, Potassium amendment, Inorganic fertilizer, Organic fertilizer

1. INTRODUCTION

Carrot (*Daucus carota* L.) belongs to the family Apiaceae (previously Umbelliferae) and thought to be domesticated in the present days Afghanistan some 5000 years ago (Mabey, 1997; Rose and Oreilly, 2006) then spread over Europe, Asia and the Mediterranean area (Dalby, 1997). It is an essential root vegetable commonly used as food (salads, soups, steamed or boiled in other vegetable dishes) mainly for its rich carotene (Amjad *et al*., 2005), protein and carbohydrates (Ahmad *et al*., 2004), and minerals like Ca, P, Fe, Na, Cu, Zn and Mg contents (Arscot and Tanumihardio, 2010). Besides, it gives medicinal benefits as the root has therapeutic action against different blood and eye diseases (Pant and Manandhar, 2007) while the leaf is used for its excellent pharmacological effects (Rossi *et al*., 2007). Nutritionally, it provides 17% of the total vitamin A consumption, making it the single major source of Beta carotene among the vegetables (Arscott and Tanumihardjo, 2010).

Carrot has gained worldwide acceptance because of its high vitamin A content, good taste, ease of production (Rossi *et al*., 2007), and relatively long storage life at low temperature (Ali *et al*., 2006). Thus, the world carrot production is continuously increasing (FAO, 2015) whereby China, the European Union, Uzbekistan, Russia, the United States, and Ukraine are the major carrot producing countries in the world (FAOSTAT, 2018). In 2018, global production of carrots (combined with turnips) was 39.99 million tons from 1131049 ha of land with Chinese 45% share in the world total (17.90 million tons). Carrot is widely cultivated since a long time in Ethiopia; but, it is often grown by small-scale farmers on a piece of land at their backyards mostly for own consumption. According to FAOSTAT (2018) report, the country's total production is 12,583 tons from 2805 ha of land with average productivity of 4.48 t ha^{-1} which is very low as compared to the world average of 35.36 t ha^{-1} mainly due to faulty nutrient application and type of fertilizer use, lack of recommended spacing, irrigation problems, and date of planting (Gerba Daba *et al*., 2018). Getachew and Mohammed, (2012) reported that in Ethiopia, carrot production has been expanding mainly due to increasing urbanization and the recognition of carrots as an income and nutrition.

Excessive amounts of inorganic fertilizers are being applied to vegetable production in order to achieve maximum yield (Abou *et al*., 2012). Specifically, most carrot growers use inorganic fertilizers by realizing higher yields than unfertilized fields (Dauda *et al*., 2008). However, the rising market cost has forced small-scale farmers to use sub-optimal amounts of common mineral fertilizers often containing N and P nutrients. Tekalign Mamo *et al*., (2014) reported that in Ethiopia only about 35% of farmers apply fertilizer on about 40% of area under crop production. Hereby, sole use of inorganic fertilizers can cause different problems on human health and environmental quality (Zhu and Chen, 2002; Arisha and Bardisi, 1999).

On the contrary, the use of organic fertilizers in vegetable crops production particularly in carrot is very limited (Emana *et al.*, 2015; Ahmed *et al.*, 2014). Organic fertilizers can provide ample types of nutrients for plant growth and development with a constant positive effect on soil for a long time (Eghball *et al.*, 2004) and vegetables produced on soils treated with these substrates are gaining great attention because of less chemical residues and better taste (Rumpel *et al.*, 1998). Organic wastes serve not only as a source of plant nutrients but also in restoring soil fertility and soil quality, thereby improving the chemical, physical and biological properties of soil (Tennakoon *et al.*, 1995). A major component of organic production is providing organic sources of nutrients to promote plant growth as well as sustain soil quality (Havlin *et al.*, 2005). The organic sources improve physic-chemical characteristics and fertility of soil in different ways such as the use of a balanced amount of all nutrients and availability of the water for plants (Warman and Havard, 1997). Specifically, cattle dung is recognized as the most desirable form of organic fertilizer due to its rich nutrient and organic matter contents that increase the growth and yield of plants via enhancing the activity of beneficial soil microorganisms and overall fertility status of soils (Gudugi, 2013; Mehedi *et al.*, 2011; Akande *et al.*, 2006). For instance, cow dung contributes a lot to reduce environmental degradation and greenhouse gas concentration (Raj *et al.*, 2014). Accordingly, Ali (1998) reported that cow dung manure improves the physical and chemical properties of the soil. Mehedi *et al.* (2012) also stated that 15 t cow dung ha^{-1} application to carrot showed the better gross (38.13 t ha^{-1}) and marketable yield (30.42 t ha^{-1}). Unfortunately, the perception to use locally available organic residues for crop production is even low and poor. As an implication, left-over of bio-mass burning (ash) is considered as waste than alternate source of fertilizer having essential elements like K, P, Mg, Ca and micronutrients (Bougnom *et al.*, 2011; Demeyer *et al.*, 2001; Saarsalmi *et al.*, 2001) plus liming role that selectively removes excessive acidic ions (H^+ and Al^{+3}) from the colloidal site of the soils (Roger and Sharland, 1997; Awodun *et al.*, 2007). Thus, applying ash to agricultural fields can compensate for nutrient losses caused by harvesting and leaching and counteract soil acidification (Saarsalmi *et al.*, 2006; Nkana *et al.*, 1998). The increase in pH as a consequence of wood ash application was found to be larger in soils with low pH (between 4 and 5) and low content of organic matter than in soils where initial pH was higher

(Ohno, 1992). After all, balanced fertilization is one of the most important means for maximizing the yield potential of carrot crops (Alemu Enkosa and Muluneh Bekele, 2019) as 30-70% increase in yields of crops has been achieved through the use of optimum and balanced mineral fertilizers (Ahmad and Hamid, 1998).

According to Hailu Regassa and Getachew Agenehu (2011), more than 50 and 25 percent of Ethiopian soils are highly responsive to the addition of nitrogen and phosphorus, respectively. Consequently, less attention has been given to other essential elements. To indicate out, application of potassium is not common for crop production in the country (EthioSIS, 2013) merely due to generalized saying of ‘‘Ethiopian soils are rich with K’’ which may not always hold true as soil fertility status is a dynamic process and varies from soil to soil and from one agroecology to the other. Moreover, different reports showed that K is declining in soils of the country (Abiye Astatike *et al.*, 2004; Abayneh Esayas and Berhanu Debele, 2006; EthioSIS, 2013) mainly due to long-term and intensive cropping as well as sole use of N and P nutrients. Thus, widespread K deficiency in soils and crops has been observed (Wassie Haile and Shiferaw Boke, 2011; Deressa *et al.* 2013). Hillete Hailu *et al.* (2015) also reported K is deficient in Vertisols of the central highlands of Ethiopia.

Carrot is among income-generating vegetable crops produced in Debre Berhan and its surroundings that is commonly characterized by excessive soil nutrient depletion due to lack of appropriate soil fertility management practices. As it is a short-duration crop that providing higher yields per unit area, carrot production can be a favorite profitable enterprise for most small-scale or resource-poor farmers (Ahmad *et al.*, 2005). In most developing countries like Ethiopia, carrot yields per unit area still remain far below the world average generally because of low technological know-how in production methods (Muendo and Tschirley, 2004). For example, carrot is a potassium-demanding plant (Kadar, 2008). But, most farmers of the area apply a sub-optimal amount of mineral fertilizers containing P and N nutrients by ignoring K, hence, there is no information on crop and location specific rate of K applications. Conversely, some farmers by default look for a locally available organic source of potassium, mostly cattle dung-cake ash, so as to have better results in carrot production. Furthermore, the combined use of both inorganic and organic fertilizers is advisable for enhancing carrot yield while providing the essential nutrients and keeping environmental quality (Rumpel *et al.*, 1998; Oleveira *et al.*, 2001). Because, in addition to the commonly used rate of N and P nutrients, integrated utilization of inorganic and organic sources of K nutrient by carrot producers can increase yield. Thus, this research was initiated with the following set of objectives.

General objective:

- To evaluate integrated effect of KCL and Cattle Dung Ash on growth, yield and quality of carrot and on soil fertility

Specific objectives:

- To determine effect of potassium chloride (KCl) on growth, yield, and quality of carrot (*Daucus carota* L.) in Debre Berhan, Central highlands of Ethiopia
- To determine effect of cattle dung ash (CDA) on growth, yield and quality of carrot (*Daucus carota* L.) in Debre Berhan, Central highlands of Ethiopia
- To determine interaction effects of potassium chloride (KCl) and cattle Dung Ash on growth, yield and quality of carrot (*Daucus carota* L.) in Debre Berhan, Central highlands of Ethiopia

2. LITERATURE REVIEW

2.1. Botany of Carrot

Carrot (*Daucus carota* L.) is an erect, biennial crop and is usually cultivated as an annual crop in the tropics (De Lannoy, 2001). The height of carrot plant ranges from 20 -100 cm and has a main taproot which becomes swollen and thickened with varying shapes and sizes. The color of the swollen root is either orange or red and the stems are solid condensed at proximal part of root. The leaves are arranged in alternate (2-3) pinnate and segmented with petiole usually long and broad at the base. Inflorescence is white or pink and it is a compound umbel, 3-7cm in diameter, borne on a branched stalk with five petals and five ovaries that are hairy. Flowers are mainly bisexual but male flowers may be present in an addition to bisexual flowers. The flowers may be often one to few dark purple sterile flowers present in the center of umbel. Once the flowers are pollinated, the umbel closes in on itself and dries out as the seeds mature (Stokes and Stokes, 1985). The fruit is oblong in shape with hook spines at ridges, the seed is oval and it contains essential oils (Tindall, 1983).

2.2. Ecological Requirements of Carrot

Carrot requires an optimum air temperature of 16-24 °C and the crop is fairly sensitive to high soil temperature which results in low germination, short root, and pale color when the temperature is over 25 °C (Tindall, 1983; Rice *et al.*, 1987); and burning of carrot seedlings (Blumil *et al.*, 1999). The crop is tolerant to a wide range of rainfall but must not be excessive which causes a change in the color of the root (Madge *et al.*, 2004). This assertion is supported by Dupriez and Leener (1990) that the soil for carrot must be moist and not waterlogged. Kononkov and Kiran (1988) stated that water requirement for carrot is more during the vegetative period. Carrot thrives well on a deep moist, well-drained, friable, sandy loam soil rich in organic matter. Carrots perform best in sandy soils with plenty of compost. In dry soils, the roots of carrots crack but in favorable soil conditions, it produces long roots (Tindall, 1983). It is well adapted to mid and high-altitude areas, both under irrigation and rain-fed conditions in many parts of Ethiopia (IAR, 1979). The crop is believed to tolerate moderately acidic to alkaline soils (Getachew and Mohammed, 2013; Blumil *et al.,* 1999). According to Tindall (1983) and Rice *et al.* (1987), the optimum soil pH for carrots ranges from 5.8-6.6.

2.3. Importance of Carrot

Carrot is an important source of carotenoids, flavonoids, vitamins (A, B, and C), sugars, and minerals, which are used for both food and health benefits. It is very helpful to maintain eyes health and also serves as an antioxidant (Dias, 2014). Chemo protective compounds are the products of carrots that protect the body against many diseases of civilization (Bystricka *et al.*, 2015). The foliage of carrot is used as forage particularly feeding horses and cattle. Carrot roots are used as vegetables for salads, soups and are also steamed or boiled in other vegetable dishes. Besides food value, different parts of carrot can be used for different medicinal purposes due to its wide range of pharmacological effects. Roots are also used for the preparation of delicious dishes such as carrot jam. The roots in the form of slices can be dehydrated. Carrot juice is a rich source of carotene and is sometimes used for coloring butter and other food items (Vanangamudi *et al.*, 2006).

2.4. Opportunity and Challenge of Carrot Production in Ethiopia

Getachew Tabor and Mohammed Yesuf, (2012) reported that in Ethiopia, carrot production has been expanding mainly due to increasing urbanization and the recognition of carrots as an income and nutrition. Similarly, Tamira Leamo, (2018) reported that many farmers in parts of the country are mainly engaged in vegetable crops production as a major source of income, primarily, because of its proximity to Djibouti and Somalia markets which it is important to save foreign currency and farmers are in using newly released variety with low cost as compared to an imported seed. Carrot are produced in a wide range of agro-ecologies from lowlands to the highlands of Ethiopia.

The low average and productivity of carrot in Ethiopia are attributed to many factors. The major ones are lack of improved seed. Poor quality seeds that are expired and those with low germination percentage and no true to type to variety are sold in the market. The type and the way producers are applying fertilizer are also the other serious problems in carrot production (Hailu *et al.*, 2008).

2.5. Nutrient Requirements of Carrot

The yield and quality of carrot are greatly affected by the fertilizers and varieties used (Win, 2010). Different varieties are characterized by different quality parameters, making some more desirable to the producers and consumers. Further, the varieties may respond differently with different nutrient sources. According to the reports of Rani and Mallareddy (2006), carrot is a heavy feeder of nutrients, and very sensitive to nutrient and soil moisture. Major mineral nutrients like N, P, and K play an important role in vegetative and reproductive phases of crop growth. Even though inorganic fertilization plays a vital role for healthy plant growth and development, it does affect soil health (Dauda *et al.*, 2008).

The stimulating effect of increasing fertilizer levels on carrot growth was consistent with the growth enhancing effect of fertilizer on crop growth in general (Ryan, 2002). This positive influence of fertilizers was reported by Sisay Hailu *et al.* (2008) who noted that pre-harvest application of organic phosphorus and inorganic nitrogen fertilizer increased the yield and yield components of carrots. Similar results to those of this study were reported by Ali *et al.* (2003) who observed increasing root yield when increasing levels of nitrogen and potassium were applied to carrots. Overall the highest level of fertilization had the highest effect on growth.

Phosphorous is directly involved in most plant growth processes such as carbohydrate breakdown, cell division, transfer of inherited characteristics, stimulation of early root growth and development, hastening maturity of plants, fruiting and seed development as well as energy transformation. It is found in highest concentrations in seeds and growing points (Troeh and Thompson, 2005). The P requirement of carrots is 40 to 80 kg ha^{-1} (FSSA, 2007). Increased root yield of carrot due to an increased rate of phosphorus application has been reported (McPharlin, 1992). Visual symptoms were not useful for diagnosing P deficiency in carrots because symptoms such as purpling of older leaves were only apparent on severely deficient plants.

Potassium is involved in plant physiological processes including photosynthesis, cell division, translocation of sugars, enzyme activity, reduction of nitrates, and subsequent synthesis into proteins (Jones, 1982). It has a vital role as a macronutrient in plant growth and sustainable crop production (Bukhsh *et al.*, 2012). Plants require K ions for opening of the stomata which is regulated by the prot pumps. Potassium helps in the regulation of the uptake of nitrates from the soil and brings a balancing effect on phosphorus uptake. It strengthens stalks of plants thus helping plants resist fungal and bacterial attacks as well as lodging. The nutrient promotes the formation of good quality seeds and fruits. It also influences the rate of transpiration and synthesis of carbohydrates and proteins and translocation of the synthesized food. But deficiency of K ions can impair plant ability to maintain these processes (Bukhsh *et al.,* 2012). It plays a major role in the transportation of water, nutrients, nitrogen utilization, and stimulation of early growth and insect and disease resistance (Lakudzala, 2013). Potassium plays important functions in plant systems by activation of more than 80 enzymes involved in different metabolic processes including protein synthesis, photosynthesis, respiration, charge balancing across the membranes of different cell organelles, particularly plasma membrane and toplast, and as osmoticum in stomatal regulation by maintenance of guard cells turgidity (Mengel, 2007).

Carrots had higher N uptake with increasing N fertilization and higher marketable yield (Chen *et al.,* 2004). The application of nitrogen fertilizer above the amount required for maximum yield increased cracking and cracking severity as well as susceptibility to cracking and breakage observed subsequent to the removal of the periderm (Hartz *et al.,* 2005). High dose of chemical fertilizers of nitrogen sources often result in a negative impact on crop yield and quality, and hence, signify optimum application of N and split application based on the nutrient requirement of the crop. Ali *et al.* (2003) reported the increased carrot root yield at the nitrogen fertilization rate of 200 kg ha^{-1} as compared to the control. This fertilization rate also led to the highest content of carotene and the lowest carotene content was recorded for plants that did not receive any nitrogen. Significant increases in yield were also reported by Gutezeit (2001) with the application of 150 kg ha^{-1} N fertilizer compared to zero fertilization on both sandy and loam soils.

2.6. Effect of Organic K Fertilizer on Carrot Yield and Quality

Organic fertilizers are all forms of organic soil amendments that originate from both livestock waste and crop residues, with the nutrients in them being mineralized by soil microbes and slowly making them available to plants over a long period of time (Lampkin, 2000). It increases soil water-holding capacity, reduces the effect of compaction, buffers the soil against rapid changes in pH and salinity and stabilizes soil structure, and improves tilth (Tisdale *et al*, 1990; Magdoff, 1998). Kiros Adele (2018) reported that organic source of nutrients has the advantage of consistent and slow release of nutrients, maintaining ideal carbon to nitrogen (C:N) ratio, improvement in microbial biomass of soil profile, without any adverse residual effects.

Organic manure was reported to increase water holding capacity of the soil making the soil to be loose and friable thereby providing favorable growth conditions for carrots (Mehedi *et al.*, 2012). Bourn and Prescott (2002) reported that organically grown fruits and vegetables contain more minerals and vitamins than conventionally grown ones. In addition, Abou *et al.* (2012) showed that, vegetative growth and yield of different crops were increased with addition of organic cattle manure. According to Frempong *et al.*, (2006), addition of organic manure improves the physical and chemical properties. Moreover, organically produced fruits, vegetables, food crops fetch much higher value not only in the international market but also in the domestic market. They are known to be devoid of any residues, thereby having positive impact on the environment and human health.

The main constraint in using organic fertilizer in most part of the world is the determination of appropriate rates for a specific variety of crops (Allemann and young, 2001). Replenishment of soil by organic matter is constrained by competing uses for crop residues and manure as livestock feed and fuel, respectively. Hence, doing this instead of using as fertilizer is estimated to reduce Ethiopia's agricultural GDP by 7% (Zenebe Gebreegziabher, 2007). The research pertaining to the use of organics and bio fertilizers in vegetable crops particularly in carrot is very limited (Leclerc *et al.*, 1991; Warman and Harvard 1996). Accordingly, balanced application of organic and inorganic sources of nutrients and its availability to crop is important to farmers and directly contribute to crop yield and beneficial to soil and farmers (Ayer *et al.*, 2019).

Organic fertilizer application for carrot crop production is recommended to improve the yield of carrots when compared to plants not received any fertilizer (Mbatha *et al.*, 2014). Kahangi (2004) has recommended the application of 10 - 20 t ha^{-1} poultry manure for improved growth and yield of carrot. Asiedu *et al.* (2007) reported that increased yield of carrot with the application of poultry manure and cow dung as compared to the control. Ahmed *et al.* (2014) also reported that the rates of cow dung application of significantly affected root fresh weight and root dry weight of carrot. With an increase in the rate of cow dung, the root fresh weight was increased. The highest root fresh weight (145.06 g $plant^{-1}$) was recorded from the plot treated with 15 t ha^{-1} of cow dung application and the lowest (76.86 g $plant^{-1}$) was recorded from the plot treated with 5 t ha^{-1} of cow dung rate. Audu and Aliyu (2013) found that cow dung is a good fertilizing material that can be used to maintain soil fertility status and improve crop production.

2.7. Effect of Inorganic Potassium Fertilizers on Carrot Yield and Quality

Ali *et al*. (2003) and Hossain *et al*. (2009) reported that increasing potassium fertilization increased shoot height, number of leaves per plant, and shoot fresh weight of carrot. El-Tohamy *et al*. (2011) also reported that potassium fertilization maintains soil fertility and there are necessities for its continuous use for carrot production. Potassium application is very important for carrot plants and carrot is a potassium-demanding plant (Kadar, 2008). It is one of the major nutrients needed by plants in high amounts to sustain plants growth (Rehm and Schmitt, 2002). It is involved in plant physiological processes including photosynthesis, cell division, translocation of sugars, enzyme activity (Jones, 1982). It is found in a relatively high concentration of clay and insoluble minerals in the soil. Due to its unavailability addition of K in crop production has to be done (FSSA, 2007).

In an experiment conducted to find out the effects of potassium fertilization and periderm damage on shelf life of carrots, Biegon (2009) observed that shoot length and both fresh and dry weights increased linearly with increasing K fertilization during the first harvest in the first year. Moreover, there were significant responses on root length, fresh weight, and diameter with an increase in the rate of potassium fertilization. Similarly, Ivanov (2001) described the role of K in maintaining soil fertility and emphasized the necessity of continuous use of K fertilizer for carrot production.

Potassium is a highly mobile element in the plant and has a specific phenomenon (Marschner, 1995). Potassium fertilization was associated with the increase in the carotene concentration in the carrot root. Lester *et al.,* (2005) has reported that K plays a vital role in carrot crop production and quality metabolism. Shikha *et al*. (2016) also reported that the yield, quality, and shelf life of carrot were increased gradually with K fertilization.

Hochmuth *et al*. (2006) indicated that potassium is required for successful carrot production. Moreover, several studies revealed the importance of K to achieve high carrot yield (Ali *et al*., 2003; Anjaiah and Padmaja, 2006; Bartaseviciene and Pekarskas, 2007) and quality of roots (Lyngdoh, 2001; Ali *et al*., 2003). Fordham and Biggs (1985) recommended the application of 0 - 55 kg ha^{-1} K for a high yield of carrots. Furthermore, carrot root yield and carotene content increased progressively and significantly with the increased application of potassium (Ali *et al.*, 2003) the increases in these traits may be due to superiority in vegetative parameter, which could be attributed stimulatory effect of K on the rate of photosynthesis, as well as transport of photosynthetic product from the leaves to storage root. Alt (1987) and Hossain *et al.* (2009) also reported that the root yield was higher in an increased rate of K fertilizer.

2.8. Effect of Integrated Nutrient Management for Carrot Production

Balanced and integrated supply of various nutrient supplements is of great relevance for quality and sustainable carrot production. Moreover, integrated use of inorganic and organic fertilizers reduces erosion, improves water infiltration, soil aeration, and plant root growth (Kumar *et al.,* 2014). Agiye and Bayor, (2017), documented that, poultry manure integrated with N, P, and K significantly improves plant height and canopy spreads of carrot. Forbes (1994) Indicated that when cow dung was fortified with NPK fertilizer and applied to sweet potato, there was higher nutrient uptake. The author indicated that this consequently led to a resultant increase in crop yield and attributed this to an increase in P, K, and Ca uptake by sweet potato.

Sharma *et al.* (2003) investigated effect of integrated use of FYM and NPK on carrot cv. Nantes and concluded that the application of 100% NPK and FYM at 10 t ha^{-1} gave the maximum yield of root. Anjaiah and Padmaja (2006) also evaluated the effects of potassium and FYM on the root yield and quality (total carotenes, total soluble solids, and total sugars) of carrot. Root yield and quality parameters increased with increasing levels of both potassium and FYM. Potassium at 120 kg ha^{-1} and FYM at 15 t ha^{-1} recorded the best yield and quality, but potassium at 80 kg ha^{-1} and FYM at 15 t ha^{-1} was the most cost-effective.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location and Soil

The experiment was conducted on research field of the College of Agriculture and Natural Resource Sciences, at Debre Berhan University during the main growing season of 2020. The study area is located 130 km away from Addis Ababa at a latitude and longitudes of 9°39’24’’N and 39°31’17’’ E, respectively with an altitude of 2782 m a.s.l (Figure 1).

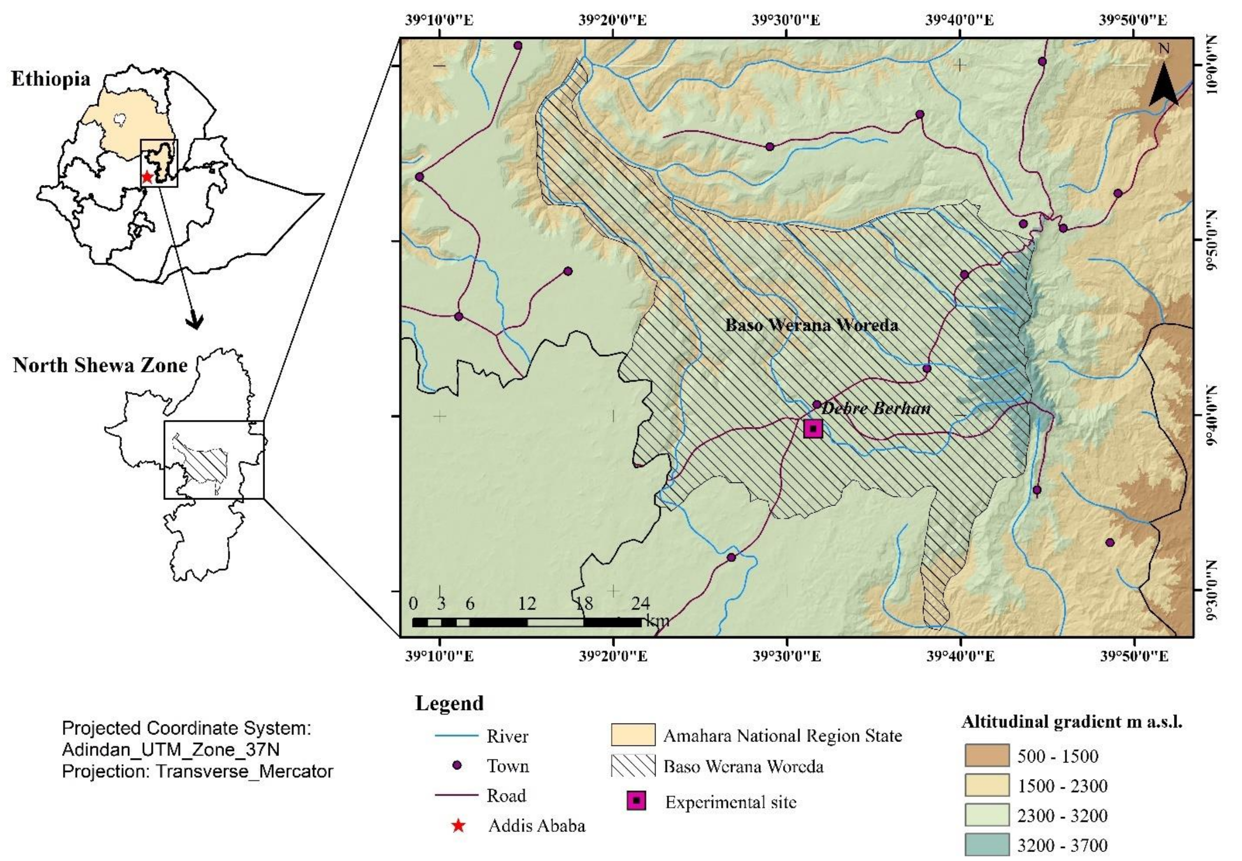

Figure 1. Map of the study area.

According to the FAO soil classification system, the most dominant soil in the area is Vertisol and cambisol (FAO, 1984) and the research site soil is verti-cambisol. The overall topography is almost plateau with an undulating slope where the soil is highly prone to erosion.

3.1.2. Climate

The data obtained from the Ethiopian National Meteorological Agency indicates that the study area is characterized by a bimodal rainfall pattern receiving a mean annual rainfall of 927.10 mm with a maximum (293.02 mm) and minimum (4.72 mm) peaks in August and December, respectively. The mean monthly maximum and minimum temperatures range from 18.3 to 21.8 ^{o}C and from 2.4 to 8.9 °C, respectively (Figure 2). According to the modern climatic zone classifications of Ethiopia (Alemneh Demissie, 2003) which was based on altitude, rainfall, average annual temperature, and length of growing season, the area belongs to cool sub-humid (*Dega*) agro-climatic zone with a frost incidence from October to December and demarcated by three seasons, locally known as *Bega* (October to January), *Belg* (February to May) and *Kermit* (June to September).

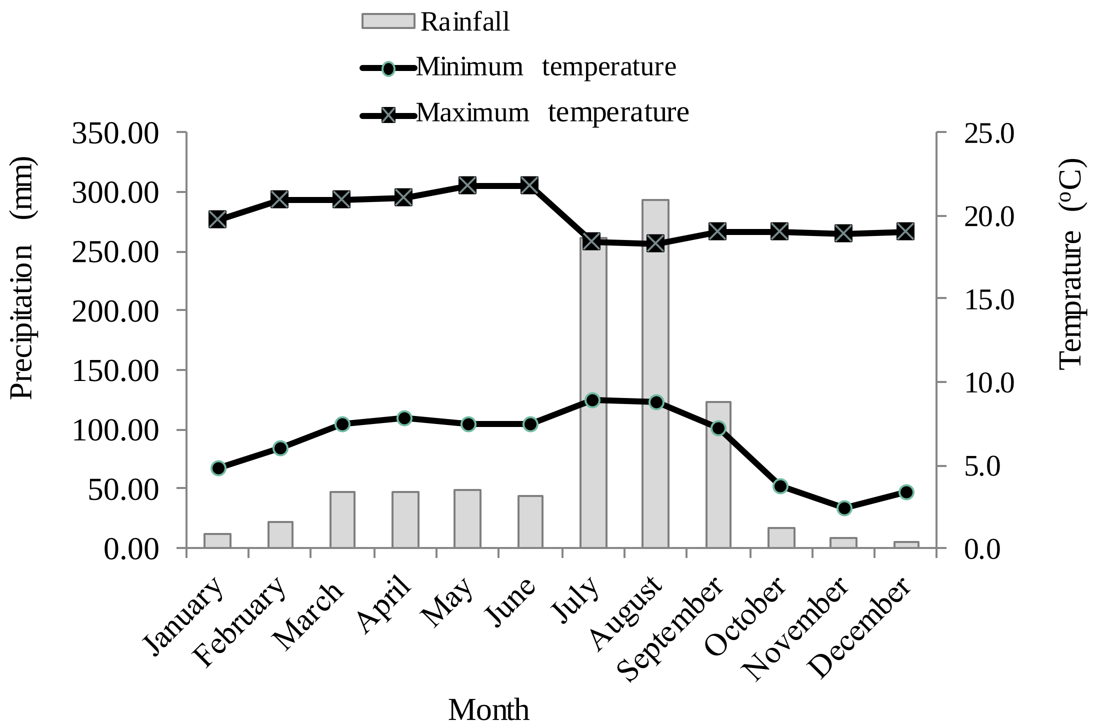

Figure 2. Mean monthly rainfall and minimum and maximum temperatures of the study area.

3.2. Experimental Materials

Carrot seeds of Nantes variety was used as test crop. Potassium chloride (KCl) and cattle dung-cake ash (CDA) were used as experimental material.

3.3. Experimental Treatments and Design

The treatments consisted of four rates of KCl (0, 50, 100, and 150 kg ha^{-1}) and CDA (0, 10, 20, 30 t ha^{-1}). All the possible treatment combinations are indicated in Table 1. The experiment was laid out using a randomized complete block design (RCBD) with three replications. The plots had 1.6 m length and 1.6 m width (2.56 m^2) and there were 1 m and 0.5 m space between blocks and plots, respectively. Each plot was consisted of 8 rows and spaced 20 cm apart. Following the specifications of the design, treatments were assigned randomly to experimental plots within a block. The outermost one row from each side of the plots and one plant at both ends of each row were considered as borders. Therefore, net plots were 1.20 m*1.40 m (1.68 m^2) which was used for data collection and the total area for experiment was 6.8*33.1 m=225.1 m^2.

Table 1. Treatment combination of four KCl levels and four Cattle Dung Ash (CDA) levels

KCl (kg ha^{-1})	CDA (t ha^{-1})	Treatment Combination
0	0	0 * 0 (control)
	10	0 * 10
	20	0 * 20
	30	0 * 30
50	0	50 * 0
	10	50 * 10
	20	50 * 20
	30	50 * 30
100	0	100 * 0
	10	100 * 10
	20	100 * 20
	30	100 * 30
150	0	150 * 0
	10	150 * 10
	20	150 * 20
	30	150 * 30

3.4. Experimental Procedures

The experimental field was prepared following the conventional tillage practice to loosen the soil since carrots prefer deep and well-drained soils. Soil was formed into a raised bed to obtain optimum drainage, maximum root length, and smoothness, and to reduce soil compaction. A well-dried cattle dung cake was collected from the local market then burned as per the local practice CDA was applied and mixed into the soil thoroughly a week before sowing. Carrot seed was directly sown via a drilling method after mixing with sand at a 1:5 ratio. After emergence, the crop was thinned out to intra-row spacing of approximately 10 cm apart. The inorganic potassium from KCl was applied during the time of planting. Phosphorus fertilizer was applied on all treatments at the rate of 100 kg $ha^{-1}$of NPSB and nitrogen fertilizer in split at a rate of 100 kg urea ha^{-1} at which the first application was during the time of planting and the second after two months of sowing. All other management practices such as weeding, earthing up and watering were kept as per the knowledge and experience of local farmers.

3.5. Soil and Cattle Dung-cake Ash Sampling and Analysis

A composite soil sample was collected in a zigzag pattern using an auger at depth of 20 cm and prepared as per the standard procedure for a pre-sowing soil test. Moreover, soil samples were collected from each plot, mixing thoroughly on the bases of their treatment effects and prepared accordingly for post-harvest soil analysis. Soil pH was estimated in 1:2.5 soil-water suspensions using a glass electrode pH meter (van Reeuwijk, 1993). The textural class was determined by using hydrometer method (Bouyoucos, 1965) and the organic carbon content is analyzed as described by Walkley and Black (1934). The exchangeable bases and CEC of the soil were determined by ammonium acetate method (Van Reeuwijk, 1993). The total N content was determined by micro-Kjeldahl method (Bremner and Mulvaney, 1982) and available phosphorous was determined using Olsen method (Olsen *et al.*, 1954).

CDA was passed through a 1 mm sieve for the analysis of its composite sample pH, EC, available P, exchangeable Ca, Mg, K and Na contents by following similar procedures as the soil samples at the Debre Berhan University and Debre Berhan Agricultural Research Center Soil Analysis Laboratories.

3.6. Data Collected

3.6.1. Phenological parameters

Days to 50% emergence: The average of days to emergence on each plot for the whole replications was taken as the actual number of days to emergence.

Days to physiological maturity: The number of days from sowing to the day on which about 75% of the plants on a plot had their lower leaves turned yellow.

3.6.2. Growth parameters

Plant height (cm): Ten randomly selected plants from the central six rows per experimental plot were tagged and used for measurement of plant height. Height of the plant was measured in cm from the ground level to the tip of the matured leaf at the time of physiological maturity.

Leaf number (No.): All active leaf petioles per plant of the ten randomly sampled plants from each treatment were counted at the time of physiological maturity.

Shoot dry weight (g): The ten plants leaves were brought to laboratory for oven drying. Then, samples were dried to a constant weight at $70^{o}C$ temperature and the dry weight was measured using digital sensitive balance.

3.6.3. Yield and yield component

Root dry weight (g): The root dry weight of randomly selected ten plants was taken after chopping and oven drying. Samples were dried to a constant weight at $70^{o}C$ temperature and the root dry weight was measured using digital sensitive balance.

Root Yield (t ha^{-1}): The total root yield of carrot from the net area of each plot was computed, expressed in kg $plot^{-1}$, and converted into ton per hectare (t ha^{-1}).

Marketable and unmarketable root number: The roots harvested from six central rows were grouped into marketable and unmarketable categories. Marketability of carrot roots was evaluated as described in (Carvalho *et al.*, 2020) roots without external defects such as cracks, unbranched, forked, or green shoulder and with small modifications, a diameter ranging from 1.5-2.5 cm and length 8-15cm, were considered as marketable root. Based on these criteria, unmarketable roots included undersized, oversized, broken, rotten, misshapen, forked, hairy, dimpled, and others. Then after the marketable and unmarketable roots were counted separately for each treatment.

Marketable root weight (kg): Fifty randomly selected carrot plant roots were categorized as marketable roots and unmarketable roots based on the above-mentioned detailed criteria. The marketable roots were weighed using digital-sensitive balance.

Unmarketable root weight (kg): Fifty randomly selected carrot plant roots were categorized as marketable roots and unmarketable roots based on the above-mentioned detailed criteria. The unmarketable roots were weighed using digital sensitive balance.

Mean root length (cm): Ten roots were randomly taken from each treatment and measured using a ruler to obtain the average root length.

Root diameter (cm): Ten randomly selected plant roots were taken from each net plot and the diameter of each was measured in the wider portion of the root using Verner caliper. The root was cut cross-sectionally at the wider portion and the diameter was measured with a caliper.

3.6.4. Quality parameter

Total soluble solids: An aliquot of juice was extracted using a juice extractor and 50 ml of the slurry was filtered using cheesecloth. The (TSS) was determined by a digital refractometer with a range of 0 to 32°Brix, and a resolution of 0.2 °Brix by placing 2 drops of clear juice on the prism. Between samples, the prism of the refractometer was washed with distilled water and dried before use. The refractometer was standardized against distilled water 0% TSS (Total soluble solids).

3.7. Partial Budget Analysis

The economic analysis was carried out by using the methodology described in CIMMYT (1988) in which prevailing market prices for inputs at sowing and outputs at harvesting were used. All costs and benefits were computed on a hectare basis in Birr. The concepts used in the partial budget analysis were the mean marketable yield of each treatment. The economic gains of the different treatments were calculated to approximate the net returns and the cost of KCL, cattle dug ash, and the income from total carrot used for further economic analysis.

Moreover, the market prices of KCl, CDA fertilizer, the marketable, and the cost of labor were getting from market assessment during the observational period.

Gross average marketable root yield (t ha^{-1}) (AvY): was an average yield of each treatment.

Adjusted yield (AjY): was the average yield adjusted downward by 10% to reflect the difference between experimental yields are often higher than the yields that farmers could expect using the same treatments; hence in economic calculations, yields of farmers are adjusted by 10% less than that of the research results (CIMMYT, 1988).

Adjustable marketable carrot yield = Average yield * (1 - 0.1)

Gross field benefit (GFB): was computed by multiplying field/farm gate price that farmers receive for the carrot when they sale it as adjusted marketable yield.

Gross field benefit (GFB) = Adjustable marketable yield*field/farm gate price for carrot.

Total variable cost (TVC): Total cost was the cost of fertilizers and application cost of fertilizers as differing dosages for the experiment. The costs of other inputs and production practices such as labor cost, land preparation, planting, weeding, and harvesting were considered the same or are insignificant among treatments.

Net Income (NI) or Net Benefit (NB): was calculated as the amount of money left when the total variable costs for inputs (TVC) are deducted from the total revenue (TR).

NB = TR – TVC

Marginal rate return (MRR): was the measure of increasing in return by increasing input.

$$\text{MRR} = \frac{\text{Change of Net Benefit } (\Delta NB)}{\text{Change of Total Variable Cost}(\Delta TVC)}$$

Marginal rate of return (MRR %): was calculated by dividing the change in net benefit by the change in total variable cost.

$$MRR(\%) = \frac{\text{Change of Net Benefit } (\Delta NB)}{\text{Change of Total Variable Cost } (\Delta TVC)} * 100$$

3.8. Data Analysis

Data obtained were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) of the Statistical Analysis System (SAS) statistical package version 9.2. All significant pair of treatment means were compared using Duncan's Multiple Range Test (DMRT) at a 5% level of significance. Pearson correlation between parameters was computed to understand the association of parameters.

4. RESULTS AND DISCUSSIONS

4.1. Physico-chemical Properties of Pre-sowing Soil

Soils of the study area had relatively higher clay and lower sand fractions (Table 2) at which the soil textural class was clay as per soil textural classification triangle of the international soil science society (ISSS) system (Rowell, 1994). Soils of this nature are good in holding water and nutrients for better crop growth and development. Since carrot requires loose and well-drained soils (Alemu Enkosa and Muluneh Bekele, 2019), soil management is a must for ensuring a profitable result from heavily textured soils of this kind.

The pH and EC were moderately acidic (Tekalign Taddese, 1991) and non-saline (USSLS, 1954), respectively. The crop grows better under non-saline (Alemu Enkosa and Muluneh Bekele, 2019; De Pascale and Barbieri, 2000) and moderately acidic to alkaline soils (Alemu Enkosa and Muluneh Bekele, 2019; Getachew and Mohammed, 2013; Blumil *et al.,* 1999); but preferentially a pH of 5.8-6.6 is best for carrot production (Rice *et al*., 1987; Tindall, 1983). The av. P content of the soil was under marginal range (Landon, 2014). Also, both the TN and OC amounts were found as moderate (Tekalign Taddese, 1991). Soils having a substantial amount of organic matter ensures yield and quality of carrot via improving the physical, chemical, and biological natures of the growing media. Carrots require adequate av. P for a satisfactory growth at which its deficiency causes a reduction in yield, with a concomitant increase in dry matter, sugar, and carotene contents of carrot root (Rao and Maurya, 1998). Nitrogen is one of the most important elements determining the nutritional quality of the carrot roots (Kansal, 1981).

The amounts of exchangeable Ca, Mg, and K were under low, low and high ranges, respectively (FAO, 2006) with CEC of medium range (Landon, 2014). Generally for most crops to present good yields, the Ca: Mg in the soil should be equivalent to a rate between 3 and 4 (Raij *et al*., 1997). In this study, the soil already had a ratio equal to 3.53, which is considered ideal for carrot production (Luz *et al*., 2009). According to Rodrigues Neto *et al.* (2021), having a relatively higher amount of Ca and K than Mg is vital for carrot production. Potassium is one of the most required nutrients by plants, for example, carrot (Kadar, 2008; Lester *et al*., 2005), at rates of two to three-fold in comparison to Ca (Taiz *et al*., 2017). Hence, the amount of Ca and Mg in the soil can allow for better K-uptake by the crop as Ca and Mg acts synergistically and antagonistically in the accumulation of K, respectively (Singh *et al*., 2012; Senbayram *et al*., 2015).

4.2. Chemical Properties of Cattle Dung-cake Ash

The elemental composition and chemical characteristics of ash (left-over of bio-mass burning) not only depend on the types (plant or animal source) and contents of the combusted material and the burning process (e.g. temperature), but also on the conditions of collection and storage of the input material (Pitman, 2006; Periömäki *et al.*, 2004; Demeyer *et al.*, 2001). Importantly, the characteristic natures of cattle dung-cake ash are determined by the quality (nutritional value) and amount of available feed, age and health of the cattle, and overall management of the farm.

As shown below (Table 2), the cattle dung-cake ash had an alkaline pH with high concentrations of exchangeable cations and CEC dominated by Ca. The alkaline pH could happen due to the raised composition of quickly soluble oxides and hydroxides of Ca, Mg, K, and Na. Etiegni and Campbell (1991) reported that oxides and hydroxides of Ca, Mg and K are the main soluble basic cations in wood ash contributing to the alkalinity which generally ranges from pH of 8.9 to 13.5 (Demeyer *et al.*, 2001) with significant amounts of exchangeable basic cations and CEC (Demeyer *et al.*, 2001; Saarsalmi *et al.*, 2001; Nkana et al., 1998). The elevated amount of exchangeable Ca than the others might be because of the variation in the extent to which they are dissolved and the rate at which they are made plant available. According to Khanna *et al.* (1994), oxides and hydroxides of K are normally dissolved quickly, while the dissolution of Ca and Mg depends on the dilution (faster when ash/water ratio is low). Additionally, the EC (salinity level) of the cattle dung-cake ash was higher (1.021 dS/m) than the soil samples probably due to the presence of carbonate salts as ash is rich with calcite ($CaCO_3$) and fairchildite ($K_2Ca(CO_3)_2$) compounds (Etiegni and Campbell, 1991; Ohno, 1992). In accordance to the results of this study, Kenzemed Kassie *et al.* (2020) have found an increase in pH, EC, exchangeable bases, and CEC of biochar made from cattle dung-cake.

Table 2. Physico-chemical properties of soil and cattle dung- ash

Sample (Treatment)	Sand	Clay	Silt	Textural class	pH (H_2O)	EC (ds/m)	Ex. Ca	Ex. Mg	Ex. K	Ex. Na	CEC	Av. P (ppm)	TN	OC
	(%)						(meg/100g)							
Pre-sowing soil														
	12	58	30	Clay	5.87	0.097	3.07	0.87	1.06	0.34	12.81	7.01	0.228	2.18
Cattle dung-cake ash														
	N/A	N/A	N/A	N/A	8.93	1.021	80.01	19.09	3.01	0.59	102.7*	1014	Nil	8.64
Post-harvesting soil														
0 * 0 (control)	14	56	30	Clay	5.86	0.089	2.98	0.93	0.98	0.33	12.44	7.13	0.223	2.08
0 * 10	12	60	28	Clay	6.14	0.152	3.99	1.53	1.27	0.35	15.24	13.14	0.228	2.14
0 * 20	14	58	28	Clay	6.18	0.229	4.25	2.09	1.78	0.39	16.40	17.65	0.237	2.18
0 * 30	12	58	30	Clay	6.19	0.342	5.12	3.04	2.46	0.43	17.72	24.01	0.243	2.21
50 * 0	10	60	30	Clay	5.88	0.113	2.94	0.91	1.15	0.32	12.46	6.89	0.217	2.14
50 * 10	10	62	28	Clay	6.04	0.167	3.82	1.34	1.42	0.33	16.24	12.88	0.225	2.17
50 * 20	10	58	32	Clay	6.18	0.273	4.22	1.83	2.05	0.36	17.38	20.90	0.237	2.24
50 * 30	10	60	30	Clay	6.18	0.365	4.76	2.88	2.60	0.39	18.67	23.85	0.247	2.27
100 * 0	10	62	28	Clay	5.87	0.118	2.88	0.86	1.24	0.32	16.36	6.97	0.224	2.08
100 * 10	16	60	24	Clay	5.89	0.185	3.67	1.18	1.67	0.34	18.34	10.12	0.227	2.09
100 * 20	14	60	26	Clay	6.10	0.223	4.12	1.59	2.19	0.36	19.58	15.66	0.233	2.14
100 * 30	16	58	26	Clay	6.17	0.264	4.24	2.16	2.72	0.39	19.82	23.53	0.244	2.17
150 * 0	10	60	30	Clay	5.89	0.127	2.79	0.82	1.42	0.31	13.01	7.08	0.217	2.03
150 * 10	10	62	28	Clay	5.96	0.196	3.36	1.09	2.13	0.35	17.82	14.84	0.223	2.09
150 * 20	10	62	28	Clay	6.09	0.262	3.54	1.31	2.34	0.37	18.62	17.79	0.227	2.14
150 * 30	14	64	22	Clay	6.16	0.394	3.78	1.52	2.81	0.41	18.94	20.78	0.237	2.20

The amounts of available phosphorus, total nitrogen, and organic carbon in the cattle dung-cake ash were recorded as 1014 ppm, nil, and 8.64 %, respectively (Table 2). The maximum levels of available phosphorus and organic carbon in the cattle dung-cake ash hopefully might be due to the excessive composition of P and OC in the cattle dung. Cattle dung is recognized as the most desirable organic fertilizer because of its high nutrient content like N, P, K, Mg, Ca and OC (Zaman *et al*., 2017). The nil amount of total N in the ash could be related to volatilization loss upon the dung-cake burning process. The content of N is low in wood ash since most compounds containing this element are almost completely oxidized and emitted as gases during incineration (Demeyer *et al*., 2001). Hereby, the available P, total N, and organic C results of this study were in line with the finding of Kenzemed Kassie *et al*. (2020).

4.3. Physico-chemical Properties of Post-harvesting Soil

All the soils had a clay textural class with relatively higher clay proportions ranging between 56 and 64 % (Table 2). There was a visible difference between the proportions of the three soil separates; but, it had no relation with the applied treatment effects. Generally, variability between the distribution of the three particles might be due to the removal of fine particles (clay and silt) by erosion or leaching and mixing up of surface and sub-surface soils during tillage and other management practice (Wakene, 2001). Because, soil texture is a stable characteristic that influences the biological, physical, and chemical properties of soils based on the nature and amounts of soil clay particles and organic matter (Ranst, 1991).

The soil pH and EC at the study site were ranged from 5.86 to 6.19 and 0.089 to 0.394 dS/m, respectively (Table 2) suggesting that the pH values were moderately and slightly acidic (Tekalign Tadese, 1991) while the EC was under non-saline (USSLS, 1954) soil conditions. Except for the sole use of KCl, there was an increment in soil pH up on both separate and combined applications of CDA with KCl fertilizers over the control. This could be more related to the liming role of CDA due to its alkaline nature and basic cations richness. Jonna (2017) and Nkana *et al*. (1998), found a rise in pH in soils treated with wood ash. The EC of the soil showed a higher increment because of an increasing solo addition of CDA than the KCl alone (Table 2). Besides, it had a rising mode with an increasing rate of amendments use in a given treatment combination. This might be due to the presence of more soluble salts in the CDA. It is confirmed that wood ash causes soil salinity due to its high contents of carbonate salts (Etiegni and Campbell, 1991; Ohno, 1992). The results of this research were in line with the work of Kenzemed Kassie *et al.* (2020) who found a rise in soil pH and EC due to the use of biochar made from cattle dung-cake.

The lowest amounts of exchangeable Ca, Mg, and Na were recorded as 2.79, 0.82, and 0.31 meq/100 g soil on plots receiving only 150 kg KCl ha^{-1}, respectively; whereby the control plot had the lowest exchangeable K (0.98 meq/100 g soil). Generally, plots from solo use of KCl fertilizer at increasing rate showed a reduction in the amounts of exchangeable Ca, Mg and Na while the exchangeable K did the opposite (Table 2). All the exchangeable bases increased upon increasing application of solo CDA with concerned highest values of Ca, Mg, K and Na as 5.21, 3.04, 2.46, and 0.43 meq/100g soil, respectively. Moreover, they showed a rising rhythm under a given combined rate of CDA and KCl with the highest values of exchangeable Ca (4.76 meq/100 g soil) and Mg (2.88 meq/100 g soil) from 50 kg KCl/ha by 30 tons CDA/ha when K (2.81 meq/100 g soil) and Na (0.41 meq/100 g soil) from 150 kg KCl/ha by 30 tons CDA/ha (Table). Hereby, the increase in the amount of the exchangeable bases might be brought due to their immediate release to the soils (Niemeyer *et al.*, 2005). On the other hand, the highest and the lowest CEC values were 19.82 and 12.44 meq/100 g soil, respectively at which all the results were under high range (FAO, 2006). As indicated above (Table 2), CEC has increased more for the combined application of CDA and KCl than either of the two amendments used separately. In addition to the little improvement of SOM and presence of more clay particles, the increased CEC might be related to the gain of a greater number of essential cations from the collective use of the fertilizers. Similar to the results of this research, Kenzemed Kassie *et al.* (2020) reviled the increase of exchangeable bases and CEC of soils due to the increasing application of biochar amendment made of cattle dung.

Results from laboratory analysis reviled that, the available P was ranged between 6.89 and 24.01 ppm, hence, it was rated as marginal and adequate levels (Landon, 2014). In general, plots receiving CDA treatment had a relatively higher amount of available P than those receiving only KCl. Moreover, it had an increasing pattern with increasing application of CDA at which the highest presence was recorded from plots having 30 tons of CDA ha^{-1} under both solo and interaction uses (Table 2). This could be due to the presence of a high amount of available P in the CDA. As a consequence of raised pH, wood ash can contribute to the increase of available P in the soil (Demeyer *et al*., 2001; Mbah *et al*., 2010; Gagnon and Ziadi, 2012). Moreover, a similar research finding was also reported by Kenzemed Kassie *et al*., (2020).

The highest and lowest amounts of total nitrogen were recorded as 0.217 and 0.247%, respectively (Table 2). According to Tekalign Taddese (1991), the amounts were under moderate category. There was an increase in concentration of TN with increasing of CDA rates implying that the use of CDA can improve the TN content in soil as Marian *et al*. (2014) reported application of 40 t ha^{-1} of cow dung biochar increased soil TN by 31.25%. Generally, N may increase due to ash application, if higher soil pH results in higher microbial activity and increased mineralization (Pitman, 2006). Khanna *et al*. (1994), reported increased rates of soil respiration and N mineralization after addition of ash from eucalyptus. Table 2 also indicates that the OC content of the soil was ranged from 2.03 to 2.27%, hence, grouped under moderate (Tekalign Taddese, 1991). Due to the application of CDA, there was an increase in values and confirmed that CDA can improve the OC content of soil as Marian *et al*. (2014) reported cow dung biochar application at the rate of 40 ha^{-1} increased soil OC content by 49% over the control after two months of addition. The results on TN and OC contents of the soil were as par with the work of Kenzemed Kassie *et al*. (2020) who found an increased mode upon using biochar made of cattle dung-cake.

4.4. Effect of KCl and CDA Rates on Phenology of Carrot

The analysis of variance (ANOVA) result indicated that the main and interactions effects of KCl and CDA did not significantly affect days to 50% emergence and 75% maturity of carrot (Appendix table 1). In agreement with this result, a non-significant difference was documented for different carrot verities for days to 75% germination in response to different nutrient treatments (Pandey and Sharma, 2017). Generally, there was an increase in days of 50% emergence and 75% maturity at the order of KCl, CDA, and KCl*CDA effects which implying these phenological parameters of carrot are more responsive for KCl*CDA, then for CDA than KCl. This might be more related with the little rise in soil salinity due to the use of KCl*CDA and CDA than KCl alone as shown above (Table 2). If soil salt content close to the seed is higher, it can cause water stress to some extent and consequently has a negative effect on germination and emergence (Okçu *et al*., 2005).

4.5. Effect of KCl and CDA Rates on Growth Parameter of Carrot

4.5.1. Plant height

Plant height of carrot was significantly ($P \leq 0.001$) affected by the main and interaction effects of KCl and CDA (Appendix Table 1). The highest value (34.55 cm) of plant height was recorded from the application of 50 kg ha^{-1} of KCl and 10 t ha^{-1} of CDA, while the lowest value (29.6 cm) was recorded from the control (0 kg ha^{-1} of KCl and 0 t ha^{-1} of CDA) treatment (Table 3). The increase in plant height of carrot might be due to the vital role of the optimal soil K on plant growth. Because, K is an important activator for dozens of enzymes, such as protein synthesis, sugar transport, and photosynthesis and it is important for ensuring better plant growth and development (White and Karley, 2010; Hepler *et al.*, 2001; Xu *et al.*, 1992). For instance, it stimulates and controls ATPase in the plasma membrane to generate acid stimulation, which then triggers cell wall loosening and hydrolase activation (Oosterhuis *et al.*, 2014). Besides, K favors the growth of meristematic tissue via its involvement in maintenance of higher osmotic potential and turgor pressure required for cell expansion, and by enhancing the effect of phytohormones involved in meristematic tissues growth (Green, 1983).

In line with the results of this research, Kenzemed Kassie *et al.* (2020) have confirmed a significant rise in height of carrot with an increasing application rate of biochar made from cattle dung-cake at which the longest and shortest plants were found upon the use of 12 and 0 t biochar ha^{-1}, respectively. Moreover, the highest and lowest plant height of carrot were recorded from the addition of 15 and 0 t cattle manure ha^{-1}, respectively (Fikadu Lebeta and Refisa Jebessa, 2019). According to Haque *et al.* (2019), a significant increase in plant height was found due to the application of K whereby the highest was recorded at 120 kg K_2O ha^{-1}. Similar results were also reported by Hossain *et al.* (2009) who found shoot height increment due to the increasing levels of potassium fertilizer.

4.5.2. Leaf number

Leaf number was significantly affected ($P \leq 0.001$) by the main and interaction effects of KCl and CDA (Appendix Table 1). The application of 50 kg ha^{-1} of KCl and 10 t ha^{-1} of CDA resulted in the highest leaf number (13.57) of carrot, while the control treatment resulted in the lowest (7.67) (Table 3). The increase in leaf number could be due to the fact that K by itself improves utilization of some other fertilizer which promotes photosynthetic activity and vegetative growth. According to Shah *et al.* (2013), a sufficient concentration of K in the soil increases the efficiency of plants for utilization of nitrogen that enhances vegetative growth. Research done on potato by Singh and Lal (2012) reported that potassium significantly affects number leave of per plant. Jakli *et al.* (2016), also reported that there can be a decrease in the number of spring-wheat leaves as well as a decrease in the leaf size under K deficiency.

In consistent with this result, Fikadu Lebeta and Refisa Jebessa (2019) reported that the highest and lowest leaf numbers of carrot were recorded from the application of 15 and 0 t cattle manure ha^{-1}, respectively. El-Tohamy *et al.* (2010) documented that vegetative growth of carrot is significantly enhanced at the higher levels of K application. Also, the increase in potassium fertilization has increased leaf numbers of carrot per plant (Ali *et al.*, 2003; Hossain *et al.*, 2009).

Table 3. Interaction effects of KCl and CDA rates on plant height and leaf numbers of Carrot

Treatments			
KCl rates (Kg ha^{-1})	CDA rates (t ha^{-1})	PH (cm)	LN $plant^{-1}$
0	0	29.60^{f}	7.67^{d}
	10	31.20^{d-f}	12.89^{a-c}
	20	29.73^{f}	12.77^{a-c}
	30	32.07^{c-e}	13.10^{a-c}
50	0	30.77^{ef}	12.20^{bc}
	10	34.55^{a}	13.57^{a}
	20	32.13^{c-e}	12.63^{a-c}
	30	32.87^{b-d}	12.16^{bc}
100	0	32.00^{c-e}	11.93^{c}
	10	30.80^{ef}	12.64^{a-c}
	20	32.93^{bc}	12.82^{a-c}
	30	34.17^{ab}	12.66^{a-c}
150	0	32.87^{b-d}	12.69^{a-c}
	10	33.40^{a-c}	12.61^{a-c}
	20	32.73^{b-d}	13.44^{ab}
	30	32.57^{b-d}	13.28^{ab}
Mean		32.15	12.44
CV (%)		2.73	5.43
KCl*CDA		***	***

Means within a column followed by the different letter(s) are significantly different from each other at $P \leq 0.05$; *** significant at $P \leq 0.001$. KCl- potassium chloride, CDA- cow dung-ash, PH-plant height, LN- leaf number, and CV-coefficient of variation

4.5.3. Aboveground biomass of carrot

Shoot dry weight was significantly affected by the main effect KCl and CDA and their interaction (Appendix Table 1). The application of 150 kg ha^{-1} of KCl and 30 t ha^{-1} of CDA in combination provided the highest shoot dry weight (15.27 gm) of carrot which was statistically similar to results of shoot dry weight from several combined applications of KCl and CDA at different rates. On the other hand, the lowest shoot dry weight (7.33 gm) was recorded from the control treatment (Table 4). The increase in biological dry masses in response to the increased levels of K might be attributed to the fact that the nutrient enhanced growth of more vegetative parts including plant height, leaf number, total leaf area and promoting enzymatic activities and enhancing the translocation of assimilates and protein synthesis as described by Devlin and Witham (1986). In addition, the role of K element in metabolism and many processes needed to promote plant vegetative growth and development (Shikha *et al*., 2016). Generally, high number of leaves leads to greater production of assimilates due to better utilization of solar radiation (Law-Ogbomo *et al*., 2018) which favored photosynthesis and led to improved yield (Law-Ogbomo and Remison, 2008).

In agreement with this result, El-Tohamy *et al*. (2010) supported that the application of K at different levels significantly increased the shoot fresh and dry biomass of carrot. The result is also in conformity with the work of Ali *et al*. (2003) and Hossain *et al*. (2009) who found that K fertilization has increased shoot height, the number of leaves per plant and shoot fresh weight. The results obtained from this study are also in accordance with those reported by Asma and Hafez (2010) who noted that a higher application of K resulted in higher biomass production in potato.

Table 4. Interaction effect of KCl and CDA rates on shoot dry weight of Carrot

Treatments		SDW
KCl rates (kg ha^{-1})	CDA rates (t ha^{-1})	$plant^{-1}$ (gm)
0	0	7.33^{e}
	10	8.63^{de}
	20	10.00^{c-e}
	30	12.32^{a-c}
50	0	9.00^{de}
	10	13.34^{ab}
	20	14.03^{ab}
	30	14.57^{a}
100	0	10.18^{cd}
	10	13.50^{ab}
	20	14.97^{a}
	30	13.39^{ab}
150	0	11.36^{b-d}
	10	14.40^{a}
	20	15.19^{a}
	30	15.27^{a}
Mean		12.34
CV		12.38
KCl*CDA		*

Means within a column followed by the different letter(s) are significantly different to each other at $P \leq 0.05$; * = significant at $P \leq 0.05$; KCl- potassium chloride, CDA- cow dung-ash, SDW, Shoot dry weight and CV-coefficient of variation.

4.6 Effect of KCl and CDA Rates on Yield and Yield Components of Carrot

4.6.1. Root dry weight

The main effects KCl and CDA and their interaction had a significant outcome on the root dry weight (Appendix Table 2).The highest root dry weight (20.61 gm $plant^{-1}$) was registered from the combined application of 50 kg ha^{-1} of KCl and 30 t ha^{-1} of CDA. Statistically similar results were recorded from the combined application 50 kg ha^{-1} of KCl and 10 t ha^{-1} of CDA and 50 kg ha^{-1} of KCl and 20 t ha^{-1} of CDA. However, the lowest root dry weight (8.00 gm $plant^{-1}$) was recorded from the control treatment (Table 5). Increment of root weight as per the application of KCl and CDA compared to the control treatment might be attributed to improved soil structure and water holding capacity upon a combined application of KCl and CDA.. The results of this research had conformity with the work of Mazed *et al.* (2015) who found that maximum root fresh weight of carrot was recorded from 25 t ha^{-1} cow dung application and the lowest from no treatment. Similarly, Fikadu Lebeta and Refisa Jebessa (2019) stated that the rates of cow dung application were significantly affected root fresh and dry weights of carrot at which the highest root fresh and dry weights were recorded from the plot treated with 15 and 5 tons of cow dung ha^{-1}, respectively.

Table 5. Interaction effect of KCl and CDA rates on root dry weight of carrot

Treatments		RDW
KCl rates (kg ha^{-1})	CDA rates (t ha^{-1})	plant^{-1} (gm)
0	0	8.00^{i}
	10	8.67^{i}
	20	9.46^{hi}
	30	10.76^{gh}
50	0	18.58^{b}
	10	20.53^{a}
	20	18.79^{ab}
	30	20.61^{a}
100	0	12.66^{fg}
	10	13.15^{f}
	20	12.55^{fg}
	30	16.94^{b-d}
150	0	13.85^{ef}
	10	15.23^{de}
	20	16.18^{cd}
	30	17.81^{bc}
Mean		14.61
CV (%)		7.54
KCl*CDA		**

Means within a column followed by the different letter(s) are significantly different to each other at $P \leq 0.05$; ns, non-significant; ** = significant at $P \leq 0.01$; KCl- potassium chloride, CDA- cow dung ash, RDW- root dry weight

4.6.2. Percent root dry matter content (%)

Percent root dry matter was significantly influenced by the main effect KCl and CDA rates and their interaction (Appendix Table 2). The highest percent root dry matter (47.17) was obtained by the combined application of 150 kg ha^{-1} of KCl and 30 t ha^{-1} of CDA which was statistically similar with results recorded by the combined application of 150 kg ha^{-1} of KCl and 20 t ha^{-1} of CDA, 50 kg ha^{-1} of KCl and 10 t ha^{-1} of CDA, and 100 kg ha^{-1} of KCl and 20 t ha^{-1} of CDA. However, the lowest percent root dry matter (32.09) was registered by the control treatment (Table 6). This might be due to the increase of potassium promotes dry matter accumulation through its action on 12 phosphorylation, stomatal opening, enzyme activation, phloem loading and also photosynthate transport from source to user points (Beringer *et al.*, 1989). In support of this idea and our result, Anjaiah and Padmaja (2006) documented that an increased level of potassium and cow manure resulted from an increased root yield and quality of carrot. Similarly, a maximum root dry matter content (17.43) of carrot was obtained from the combined application of potassium and boron at a rate of 75 kg ha^{-1} and 15 kg ha^{-1}, which was by far high compared with the dry content of 3.42 obtained from the non-treated control (Subba *et al.*, 2017). Furthermore, increased root dry matter of content of potato crop was reported in optimum application of fertilizers (Rai *et al.*, 2010).

4.6.3. Root yield (t ha^{-1})

Root yield was significantly affected by the main effect KCl, CDA, and their interaction (Appendix Table 3). The highest root yield (22.15 t ha^{-1}) was observed by the combined application of 50 KCl kg ha^{-1} and 10 t ha^{-1} CDA; but, it was statistically similar with the combined application of 100 kg ha^{-1} of KCl and 10 t ha^{-1} of CDA. The lowest root yield (16.88 t ha^{-1}) was recorded by the control treatment (Table 6). This could be due to major roles of K in several metabolic processes such as protein synthesis and osmotic adjustment, carbohydrate translocation and metabolism (Marschner, 1995) that eventually increase crop yield. Potassium status of plants has a significant effect on transport and distribution of photosynthetic products (Pettigrew, 2008). Sufficient potassium supply can establish osmotic potential in the phloem and help to transfer photosynthate from source to sink organs (Cakmak, 2005). Nevertheless, the loading of photosynthate in phloem of K deficient plants is inhibited and the transport to roots is significantly reduced (Gerardeaux *et al.*, 2010). Carrot is potassium demanding crop and it the reason respond in this study.

The result is in accordance with the work of Shikha *et al.*, (2016) who reported that carrot yield and quality were increased gradually with K fertilization and highest yield was recorded from 70 kg ha^{-1}; however, a statistically similar yield was obtained from 50, 90 and 110 kg of K ha^{-1}. With regard to organic K containing fertilizer, Kenzemed Wassie *et al.* (2020) reported that total yield of carrot resulted from increased rates of applied biochar at which the highest total root yield (44037.0 kg ha^{-1}) was obtained from the plot applied with biochar at the rate of 12 t ha^{-1}, while the lowest (30208.00 kg ha^{-1}) was obtained from plots without biochar. Besides, it was reported that application of cattle manure at 10 t ha^{-1} increased carrot root weight by 48.8 % compared to the non-fertilized control treatment (Daba *et al*., 2018). Similarly, Fikadu and Refisa (2019) reported that the highest and lowest yields of carrot plant were recorded by 15 and 5 t ha^{-1} cow dung application, respectively. Selam (2010) also found that K applied at 100 kg ha^{-1} in the form of KCl increased the total tuber yield by 252% over the control. Panique *et al.* (1997) the authors observed that application of K fertilizer, as chloride can have tremendous effects on assimilating distribution and therefore, on yield formation of potato. Omran *et al.* (1991) also mention that an adequate supply of potassium strengths stems to prevent lodging, increases yield, and improves tuber quality.

4.6.4. Root length and diameter

The main effects KCl and CDA did not significantly affect the root length; but, their interaction significantly ($P \leq 0.05$) affected this parameter (Appendix Table 2). The longest root length (11.44 cm) was recorded by the application of 50 kg ha^{-1} of KCl and 10 t ha^{-1} of CDA rates. However, the lowest root length (9.48 cm) was recorded by the control treatment (Table 6). Root diameter was significantly ($P \leq 0.001$) affected by the main effect of KCl and the interaction effect of KCl and CDA; while, the main effect of CDA did not significantly affect this parameter (Appendix table 2). The widest root diameter (2.10 cm) was recorded by the application of 50 kg ha^{-1} of KCl and 30 t ha^{-1} of CDA when the thinnest root diameter (1.59 cm) was recorded by the control treatment (Table 5). Root length and diameter increased by increasing K might be due to superiority in vegetative growth parameters. The big photosynthesizing foliage did produce plenty of photosynthate for the root. These results agree with report of Hossain *et al*., (2009) who indicated that the stimulatory effect of K on rate of photosynthesis, as well as, transport of photosynthetic product from the leaves to the storage root. Reduction in the length and diameter of stem internodes and of root development due to K deficiency has also been described by Singh and Sharma (1988).

The of results this research agreed with the findings of Kenzemed Kassie *et al*. (2020) who confirmed that the root length and diameter of carrot were significantly influenced by application of biochar at which the longest and thickest root was obtained by application of 12 t biochar ha^{-1} whereas the shortest and thinnest root of carrot was recorded from control treatment. This result is also in consistent with reports of Hague *et al*. (2019) who indicated that root characteristics;

(root length and root diameter) of carrot plant were significantly improved with the application of K compared to the unfertilized control. In addition, Sharangi and Paria (1996) described that the application of higher levels of K produced longer and wider carrot roots than the lower levels and the un-fertilized control.

Table 6. Interaction effect of KCl and CDA rates on yield and yield components of Carrot

Treatments		RD plant^{-1} (cm)	RL plant^{-1} (cm)	RDM (%)	Yield ha^{-1} (t)	uMRY (kg)
KCl (kg ha^{-1})	CDA (t ha^{-1})					
0	0	1.59^{g}	9.48^{c}	32.09^{e}	16.88f	0.187^{a-f}
	10	1.74^{e-g}	9.97^{bc}	32.68^{e}	18.65^{c-f}	0.200^{a-d}
	20	1.76^{d-f}	10.43^{a-c}	33.39^{de}	17.19^{ef}	0.120^{fg}
	30	1.81^{c-f}	10.54^{a-c}	37.32^{b-e}	18.63^{c-f}	0.140^{c-f}
50	0	1.80^{c-f}	9.90^{bc}	33.33^{de}	18.94^{c-e}	0.136^{d-g}
	10	1.82^{c-f}	11.44^{a}	41.85^{ab}	22.15^{a}	0.140^{c-f}
	20	1.65^{fg}	10.32^{a-c}	34.71^{c-e}	18.67^{c-f}	0.163^{b-g}
	30	2.10^{a}	9.83^{bc}	39.43^{b-d}	19.02^{c-e}	0.110^{fg}
100	0	1.67^{fg}	9.49^{c}	37.31^{b-e}	18.51^{c-f}	0.193^{a-e}
	10	1.75^{d-g}	9.99^{bc}	39.57^{b-d}	21.78^{ab}	0.130^{d-f}
	20	1.92^{b-d}	10.87^{ab}	41.52^{ab}	19.50^{cd}	0.166^{a-g}
	30	1.91^{b-e}	10.53^{a-c}	39.88^{b-d}	19.44^{cd}	0.103^{g}
150	0	1.76^{d-f}	10.51^{a-c}	32.24^{e}	17.69^{d-f}	0.126^{fg}
	10	1.82^{c-f}	11.02^{ab}	40.74^{bc}	19.35^{cd}	0.136^{d-g}
	20	1.98^{a-c}	10.12^{bc}	41.93^{ab}	20.22^{bc}	0.100^{g}
	30	1.99^{ab}	10.74^{ab}	47.17^{a}	19.80^{c}	0.100^{g}
Mean		1.81	10.32	37.82	19.15	0.141
CV (%)		5.06	5.89	9.06	5.51	22.63
KCl*CDA		***	*	*	*	**

Means within a column followed by the different letter(s) are significantly different to each other at $P \leq 0.05$; * significant at $P \leq 0.05$; ** = significant at $P \leq 0.01$; *** significant at $P \leq 0.001$. CDA- cow dung ash, RD- root diameter, RL- root length, RDM- root dry matter, uMRY- unmarketable root yield, and CV- coefficient of variation.

4.6.5. Marketable and unmarketable root numbers and yields of carrots

The main effect CDA significantly ($P \leq 0.001$) influenced marketable root number and un-marketable root number of carrot (Appendix Table 3). However, the main effect of KCl and the interaction effect of KCl and CDA did not significantly affect marketable and un-marketable root numbers of carrot. The highest marketable root number (44.67) was recorded by the application of CDA at a rate of 10 t ha^{-1} but statistically similar with the application of CDA at a rate of 20, and 30 t ha^{-1}. However, the lowest marketable root number (37.92) was recorded from the control treatment (Table 7). On the contrary, the highest un-marketable root number (12.08) was registered by the control treatment whereas application of CDA at a rate of 10 t ha^{-1} resulted in the lowest un-marketable root number (5.33) of carrot (Table 7). Consequently, marketable root yield was significantly ($P \leq 0.05$) influenced by the main effect of CDA while the main effect of KCl and the interaction effect of both did not influence this parameter. Whereas, unmarketable root yield was significantly affected by both the main effect of KCl and CDA and their interaction (Appendix Table 3). The highest marketable yield (1.36 kg) was recorded by the application of 10 t ha^{-1} of CDA (Table 7). But, the lowest marketable yield (1.06 kg) of carrot was obtained by the control treatment (Table 7). The lowest unmarketable root yield (1 kg) was obtained by combined application of 150 kg of KCl ha^{-1} with both 20 and 30 t ha^{-1} of CDA which was statistically different from the unmarketable yield of 1.87 kg obtained by the control treatment (Table 6). Increment marketable root numbers, roots without external defects such as cracks, unbranched, forked, or green shoulder; with a good diameter and a length of roots, obtained from CDA amended plots than non-treated (control) plots in this study confirm this. Loose soil, following application of manures, may probably have favored root growth and expansion leading to increased length and shoulder diameter of carrots (Jeptoo *et al*., 2012). Nagrea *et al*, (2012) have also noted that potassium ensures a better-quality crisper, and also enhances keeping quality after harvesting; wilting is retarded. Also, it was stated that increased amounts of K enhance the ability of plants to resist diseases, insect attacks, cold and drought stresses, and other adverse conditions (Alemu Enkosa and Muluneh Bekele, 2019). The tendency of marketable yield increment might be attributed to improved nutrient availability and better soil structures that could have favored growth and quality improvement of carrot root in CDA supplied plots compared with the non-supplied control plots. This argument is supported by Parry *et al*. (2005), who found that organic manures are known to have the ability to supply both macro and micronutrients required for growth and final economic yield of crops. In addition, Madge *et al*. (2003), stated that K is a key element in influencing quality of fruits and vegetables.

Though it is not always true the trend seems the unmarketable yield of carrot root is becoming decreased as the combined application of potassium from KCl and CDA. This result is at par with reports of Biegon, (1995), who noted that unmarketable yield of carrot is decreased with an increase in the rate of potassium fertilizer. In accordance with the results of this research, Kenzemed Kassie *et al*. (2020) revealed that both marketable and unmarketable carrot yields were significantly influenced by application of biochar at which the highest marketable and unmarketable root yields were obtained from the plot treated with 12 t ha^{-1} of biochar, while the lowest marketable and unmarketable root yields were obtained from plots without biochar utilization. On the contrary, Greenwood *et al.*, (1980), reported that increasing in potassium fertilizer increased unmarketable yields of carrot on sandy loam with 69 ppm of K.

Islam and Momin (2004), reported that quality improvement of vegetables and fruits has been observed as one of the beneficial effects of organic manures.

4.6.6. Total soluble solids

The main effect of CDA significantly ($P \leq 0.001$) influenced the Total soluble solid (TSS) while that the main effect of KCl and the interaction effect of both did not affect this parameter (Appendix table 3). The highest TSS (8.34) were recorded by the application of 30 and 20 t ha^{-1} of CDA (Table 7) and the lowest (6.24) TSS of carrot were obtained from the control treatment (Table 7). These increment of TSS content with potassium amendment from CDA might be attributed to potassium role in increasing photosynthetic activity which also plays a paramount role for high translocation of photo assimilates from the leaves to roots of carrot plant. Moreover, enhanced TSS following application of higher rates of CDA observed in this study could be attributed to enhanced levels of macro and micronutrients organic fertilizers like CDA required for growth and quality of plant roots. These arguments are supported by previous works of Ahmad *et al*. (2005), who documented a positive effect of farmyard manure on TSS content of carrots.

This result is at par with a previous report of El-Nasr and Ibrahim (2011), who indicated that the interaction effect between different rates of potassium and its foliar application had a significant effect on TSS and carotenoids content of carrot roots. Besides, increased TSS content of carrot root were reported at higher levels of bio-slurry applications (Jeptoo *et al*., 2012).

Table 7. Effect of CDA rates on marketable root number, un-marketable root number, marketable root yield, total soluble solids (TSS) of Carrot

CDA rates (t ha^{-1})	MRN	uMRN	MRY (kg)	TSS (brix)
0	37.92^{b}	12.08^{a}	1.06^{b}	6.24^{b}
10	44.67^{a}	5.33^{c}	1.36^{a}	8.22^{a}
20	42.75^{a}	7.67^{b}	1.08^{b}	8.34^{a}
30	43.08^{a}	6.92^{bc}	1.27^{ab}	8.34^{a}
Mean	42.11	8.00	1.19	7.78
CV (%)	6.37	31.66	23.53	20.17
Significant level	***	***	*	***

Means within a column followed by the different letter(s) are significantly different to each other at P ≤ 0.05; ns = non-significant; * = significant at $P \leq 0.05$; *** = significant at $P \leq 0.001$. CDA- cow dung ash, MRN- marketable root number, uMRN- un-marketable root number, MRY- marketable root yield, TSS-total soluble solid and CV- coefficient of variation.

4.7. Correlation Analysis of Growth Parameters, Yield and Yield Components of Carrot

The Pearson correlation analysis was executed to determine a simple correlation coefficient between growths, yield and quality parameters as a result of applied KCl and CDA fertilizer. Plant height was significantly and positively correlated with root dry matter content ($r=0.50^{***}$), leaf number ($r=0.47^{***}$), and root yield ($r=0.39^{**}$), root diameter ($r= 0.35^{*}$), and marketable root yield ($r= 0.32^{**}$) (Table 9). This might be due to potassium from KCl and CDA application is very important for carrot plants in vegetative growth which brings wider and heavier roots.

Root yield also had a positive and significant correlation coefficient with root dry matter ($r=0.48^{***}$), root dry weight ($r=0.46^{**}$), plant height and leaf number ($r=0.39^{**}$) and shoot dry weight ($r=0.36^{**}$). Marketable root number had a significant and positive correlation with marketable root yield ($r=0.50^{**}$), root length ($r=0.30^{**}$), and plant height ($r=0.29^{*}$) (Table 9). The result further showed that marketable root number is strongly significant and negatively correlated with unmarketable root number ($r=-0.98^{***}$). Furthermore, root dry matter had a positive and significant correlation coefficient with shoot dry weight ($r=0.56^{***}$), plant height ($r=0.50^{***}$), and root yield ($r=0.48^{***}$), and root dry weight ($r=0.35^{*}$) (Table 9). These increases of root and yield parameters of carrot with significant and positive correlation with most of the growth parameters are explained by the increased vegetative growth of the plant resulted in the production of high photo assimilation that in turn resulted in increased root yield and quality. In agreement with this, Gezahegne *et al.* (2014) and Simon Koroto, (2019), reported that, improved vegetative growth is attained by the use of organic and inorganic fertilizer which in turn resulted in increased root yield.

Table 8.Result of Correlation analysis of growth, yield and quality parameter of carrot as influenced by application of KCl and CDA at different rates

PAR	PH	LN	RY	RL	RD	MRN	uMRN	MRY	uMRY	SDW	RV	TSS	RDW	RDM
PH	1													
LN	0.47^{***}	1												
RY	0.39^{**}	0.39^{**}	1											
RL	0.25^{ns}	0.29^{**}	0.23^{ns}	1										
RD	0.35^{*}	0.21^{ns}	0.28^{*}	-0.03^{ns}	1									
MRN	0.29^{*}	0.22^{ns}	0.35^{*}	0.30^{**}	0.06^{**}	1								
uMRN	-0.28^{ns}	-0.21^{ns}	-0.33^{*}	-0.23^{**}	-0.05^{ns}	-0.98^{***}	1							
MRY	0.32^{**}	0.18^{ns}	0.38^{**}	0.39^{**}	0.24^{**}	0.50^{**}	-0.47^{***}	1						
uMRY	0.03^{ns}	-0.20^{ns}	0.03^{ns}	0.08^{ns}	0.09^{ns}	-0.02^{ns}	0.01^{ns}	0.03^{ns}	1					
SFW	0.23^{ns}	0.29^{**}	0.41^{**}	-0.05^{ns}	0.18^{ns}	0.40^{**}	-0.37^{**}	0.21^{**}	-0.01^{ns}					
SDW	0.55^{***}	0.54^{***}	0.36^{**}	0.11^{ns}	0.20^{ns}	0.15^{ns}	-0.13^{ns}	0.06^{ns}	-0.06^{ns}	1				
RV	0.20^{*}	0.09^{ns}	0.53^{**}	0.18^{ns}	0.20^{ns}	0.09^{ns}	-0.06^{ns}	0.28^{ns}	0.01^{**}	0.09^{ns}	1			
TSS	0.17^{ns}	0.13^{ns}	0.41^{*}	0.34^{*}	0.06^{ns}	0.20^{ns}	-0.19^{ns}	0.42^{*}	0.31^{*}	0.02^{ns}	0.23^{ns}	1		
RFW	0.48^{***}	0.37^{*}	0.05^{**}	-0.01^{ns}	0.15^{ns}	-0.13^{**}	0.14^{ns}	0.01^{ns}	0.27^{ns}	0.46^{***}	0.28^{ns}	0.21^{ns}		
RDW	0.37^{***}	0.34^{*}	0.46^{***}	0.16^{ns}	0.27^{ns}	0.02^{ns}	-0.03^{ns}	0.05^{ns}	-0.11^{ns}	0.49^{**}	0.15^{ns}	0.08^{**}	1	
RDM	0.50^{***}	0.38^{**}	0.48^{***}	0.09^{ns}	0.19^{ns}	0.26^{ns}	0.21^{ns}	0.24^{ns}	-0.11^{ns}	0.56^{***}	0.20^{ns}	0.20^{ns}	0.35^{*}	1

Where: PAR=parameter, PH-plant height, LN-leaf number per plant, RY- root yield RL-root length, RD-root diameter, MRN-marketable root number, uMRN-unmarketable root number, MRY-marketable root yield, uMRY-unmarketable root yield, SDW-shoot dry weight, RV-root volume, TSS-total soluble solid , RDW- root dry weight, RDM- root dry matter. ns = non-significant; * = significant at $P \leq 0.05$; ** = significant at $P \leq 0.01$, and *** = significant at $P \leq 0.001$.

4.8 Result of Partial Budget Analysis

The results of the partial budget analysis revealed that applying 50 kg KCl ha^{-1} and 10 t ha^{-1} of CDA in combination had the highest net benefit (181,540.00 Birr ha^{-1}) and MRR of 958.824% followed by sole application of 30 t ha^{-1} of CDA ha^{-1} with a net benefit of 172,260.00 Birr ha^{-1} and MRR of 807.059 % and sole application of 10 t ha^{-1} of CDA ha^{-1} with a net benefit of 153,660.00 Birr ha^{-1} and MRR of 637.647 % (Table 10). Thus, application of KCl and CDA at a rate of 50 kg ha^{-1} and 10 t ha^{-1}, respectively, sole use of CDA at rates of 30 and 10 t ha^{-1} are recommended as first, second and third options, respectively for carrot production in the study area.

Table 9. Result of partial budget and marginal rate of return analysis for response of carrot production to different rates of KCl and CDA

Treatments							
KCl rates (kg ha^{-1})	CDA rates (t ha^{-1})	AvMRY (t ha^{-1})	AjMRY (t $ha^{-1)}$	TVC (Birr)	GFB (Birr)	NB (Birr)	MRR (%)
0	0	6.73	6.06	-	121,140.00	121,140.00	-
	10	8.82	7.94	5,100.00	158,760.00	153,660.00	637.647
	20	7.85	7.07	10,200.00	141,300.00	131,100.00	D
	30	10.42	9.38	15,300.00	187,560.00	172,260.00	807.059
50	0	7.43	6.69	1,100.00	133,740.00	132,640.00	279.014
	10	10.43	9.39	6,200.00	187,740.00	181,540.00	958.824
	20	6.94	6.25	11,300.00	124,920.00	113,620.00	D
	30	8.30	7.47	16,400.00	149,400.00	133,000.00	380.00
100	0	6.94	6.25	2,200.00	124,920.00	122,720.00	72.394
	10	8.30	7.47	7,300.00	149,400.00	142,100.00	380.00
	20	8.30	7.47	1,2400.00	149,400.00	137,000.00	D
	30	9.54	8.59	17,500.00	171,720.00	154,220.00	337.647
150	0	8.30	7.47	3,300.00	149,400.00	146,100.00	57.183
	10	10.21	9.19	8,400.00	183,780.00	175,380.00	574.118
	20	6.94	6.25	13,500.00	124,920.00	111,420.00	D
	30	6.94	6.25	18,600.00	124,920.00	106,320.00	D

Where: AvMY-average marketable yield; AjMY- adjustable marketable yield; TVC-total variable cost; GFB-growth field benefit; NB-net benefit; D-Dominated treatment; Selling price of carrot at farm gate = 20 Birr kg^{-1}; Purchasing costs of KCl fertilizer= 20.00 Birr kg^{-1}; Cost of CDA = 500 Birr t^{-1}; Labor cost = 100 Birr Man-day^{-1}

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Carrot is one of the commonly produced income-generating vegetable crops for farmers in Ethiopia. However, its productivity is very low compared with the crop yield potential and its productivity in other countries of the world. The most yield-limiting factors are soil nutrient depletion, low soil inputs, land degradation and poor land management practices, which results in deficiency of essential nutrients including potassium. The major causes of soil fertility decline in Ethiopia are soil erosion, low inherent soil fertility, limited availability and continuous use of minerals, DAP and urea fertilizers, depletion in soil organic matter all of which are the result of inappropriate land management practices. The objectives of the study is evaluating the effect of (KCl) and [cattle dung-cake ash (CDA)] at different rates on growth, yield, and quality of carrot.

In this study the effect of different rates of inorganic (KCl) and organic [cattle dung- ash (CDA)] was evaluated on phenological, growth, yield and yield components and quality parameters of carrot. The study revealed that, alone and combined application of KCl and CDA at different levels significantly determined most of the parameters evaluated in the field experiment. Of all the treatment combinations evaluated, a combined application of 50 kg ha^{-1} of KCl and 10 t ha^{-1} of CDA provided the highest and consistent result for different yield, yield components and quality parameters of carrot. This implies that, though growth, yield, yield components, and quality of carrot is improved by the application of potassium from KCl and CDA, it is not always true hence the increment was not significant beyond the optimum. In addition, a partial budget analysis also confirmed that, the combined application of 50 kg ha^{-1} of KCl and 10 t ha^{-1} of CDA is the most economical treatment combination to reduce cost of production and increase the profit gained. Hence, the combined application of 50 kg ha^{-1} of KCl and 10 t ha^{-1} of CDA is the optimum potassium for improving the yield and quality of carrot in the study area and also beyond this rate show value reduction in some parameters But, to give a better recommendation about KCl and CDA rates for carrot production improvement that fits for carrot production to the study area and other potential areas of carrot production further researches need to be done at different locations and different seasons and more varieties.

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7. APPENDICES

Appendix Table 1. Mean square from analysis of variance (ANOVA) on phenological and agronomic data of carrot

Source of Variance	DF	ED	MD	PH	LN	SDW
Rep.	2	0.271^{ns}	1.688^{ns}	2.787^{*}	6.617^{***}	2.785^{ns}
KCl	3	0.243^{ns}	0.965^{ns}	12.359^{***}	4.227^{***}	51.061^{***}
CDA	3	0.409^{ns}	1.188^{ns}	5.925^{***}	9.297^{***}	32.545^{***}
KCl*CDA	9	0.558^{ns}	2.409^{ns}	4.090^{***}	4.552^{***}	5.509^{*}

Where: DF-degree of freedom, Rep.-replication, ED-emergency date, MD-maturity date, PH-plant height, LN-leaf number, and SDW-shoot dry weight *significant at $p \leq 0.05$; ** significant at $p \leq 0.01$; *** significant at $p \leq 0.001$; ns= non-significant at $p > 0.05$.

Appendix Table 2. Mean square from analysis of variance (ANOVA) on different root and related parameters of Carrot

Source of Variance	DF	CD	RD	RL	RV	RDW	RDM
Rep	2	0.0466^{*}	0.004^{ns}	0.755^{ns}	58.5208^{ns}	6.468^{ns}	43.353^{*}
KCl	3	0.0066^{ns}	0.061^{***}	0.364^{ns}	1013.42^{ns}	2022.29^{***}	104.852^{***}
CDA	3	0.0149^{ns}	0.027^{ns}	0.684^{ns}	761.472^{ns}	183.287^{***}	108.874^{***}
KCl*CDA	9	0.0095^{ns}	0.065^{***}	1.126^{*A}	500.361^{ns}	26.380^{*}	26.481^{*}

Where: DF-degree of freedom, CD-crown diameter, RD-root diameter, RL-root length, RV-root volume, RDW-root dry weight, RDM-root dry matter, =. *significant at $P < 0.05$; ** significant at $P \leq 0.01$; *** significant at $P \leq 0.001$; ns= non-significant at $P \geq 0.05$.

Appendix Table 3. Mean square from analysis of variance (ANOVA) on different yield and quality of Carrot

Source of Variance	DF	TSS	MRN	uMRN	MRY	uMRY	Yield
Rep.	2	0.3180^{ns}	12.333^{ns}	17.438^{ns}	0.0002^{ns}	0.0010^{ns}	0.011^{ns}
KCl	3	0.3487^{ns}	14.799^{ns}	18.167^{ns}	0.005^{ns}	0.0068^{**}	0.205^{***}
CDA	3	2.4501^{***}	101.909^{***}	100.278^{***}	0.2516^{*}	0.0085^{**}	0.261^{***}
KCl*CDA	9	0.2370^{ns}	7.743^{ns}	7.037^{ns}	0.0874^{ns}	0.0047^{**}	2.533^{*}

Where: DF-degree of freedom, Rep.-replication, TSS-total soluble solids, MRN-marketable root number and uMRN-unmarketable root number, MRY-marketable root yield, uMRY, unmarketable root yield, and yield. *significant at $P \leq 0.05$; ** significant at $P \leq 0.01$; *** significant at $P \leq 0.001$; ns= non-significant at $P > 0.05$.