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Response of *Nantes* Carrot (*Daucus Carota* L.) variety to blended NPS and K fertilizers in Sodo Zuria Woreda of Wolaita Zone, Southern Ethiopia

Mengistu Dinato, Abraham Bosha and Birhanu Lencha*

Department of Horticulture, College of Agriculture, Wolaita Sodo University, P.O. Box 138,

*Corresponding author e-mail: birelencha@gmail.com

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Abstract

Carrot is the cheap source of carotenoids, vitamins, and minerals and has the potential to tackle chronic Vitamin A malnutrition in Ethiopia and generate income for resource-poor farmers. However, its productivity was low due to low soil fertility as one of the many constraints. Therefore, this field experiment was conducted to assess the response of Nantes carrot variety to blended NPS and KCl fertilizer rates at Sodo Zuria Woreda. The experiment consisted of four rates of NPS (0, 50, 100 and 150 kg/ha^{1}) and four rates of KCl (0, 71, 142 and 213 kg/ha^{1}) fertilizers in factorial arrangement and laid out in randomized complete block design with three replications. The results of analyses of variance revealed that NPS and KCl fertilizers as well as the interaction effects of the two fertilizers had significant effects on yield components and root yield of the commercial variety except root length, which was not significantly influenced by interaction effects of the two fertilizers. The highest total and marketable root yield of 30.5 and 24.6 t ha^{-1}, respectively, was obtained by the combined application of 150 kg/ha^{1} NPS and 213 kg/ha^{1}KCl fertilizers. The highest marginal rate of return (MRR %) (2755.97%) was obtained from 150 kg NPS ha^{-1} without KCl fertilizer application. However, the combined application of 150 kg ha^{-1} NPS and 213 kg ha^{-1} KCl fertilizers bear the highest total net benefit of 118881 Birr per hectare with MRR of 1385%, which was above the minimum acceptable range. This could be used to obtain high root yield and better economic return to producers in the study area.

Keywords: Marketable, Marginal rate of return, Root yield, Soil fertility

Introduction

Carrot (*Daucus carota* L.) is herbaceous, nutritious and delicious root vegetable that belongs to the Apiaceae family (Peirce, 1987). The domestic carrot originated from Central Asia (Iorizzo *et al.,* 2013). In Ethiopia, during the 2019 cropping season, the crop was cultivated on 2,556.05 hectares of land with a total production of 10, 1482.29 tons and a national average yield of 3.97 t

ha^{-1} (CSA, 2019). Cultivation of carrot helps as a job opportunity for most small scale, resource-poor farmers since carrot is a short duration crop and higher yields can be obtained per unit area and income generator for those who are jobless (Ahmad et al., 2005). Continuous cultivation without fallow periods, total crop residue removal from the farm and inadequate soil management were common practices in Wolaita area (Fanuel et al., 2016), thus low soil fertility is the major challenge for the productivity of carrot.

Different research and development activities have been undertaken on carrot crop response to the application of various nutrients across soil types, agro-ecologies and cropping systems to mitigate the problems. To date, the highest total root yield of carrot was obtained by the application of various rates of plant nutrients like N, P, K and S (Nesa, 2007; Yesmin, 2014; Dagne, 2015; Satish et al., 2016; Shikha et al., 2016). These showed the identification of types and amount of mineral nutrients required to the specific production area.

However, in the study area, the absence of recommendations for the rates of the newly introduced blended NPS and potassium fertilizers for carrot production is still one of the major constraints to increase the yield of the crop. Therefore, this research was initiated to mitigate carrot production challenge with the objectives of assessing the response of *Nantes* carrot variety to blended NPS and KCl fertilizers rates and estimating the cost-benefit for the rates of NPS and KCl fertilizers for carrot production.

Materials and methods

Description of the study site

The experiment was conducted at Waja Kero Kebele, Sodo Zuria Woreda in Wolaita zone of Southern Ethiopia in the 2019 cropping season. The experimental site is located at 326 km to the south from Addis Ababa; geographically located at an altitude of 1920 m asl with 6^{o} 88’ N and 37 ^{o} 72’ E latitude and longitude, respectively. The mean annual rainfall of the area is 1200 mm with a bimodal pattern that extends from February to September. The mean annual minimum and maximum temperatures of the area is 13.6^{o}C and 24.2^{o}C, respectively. The pH of soil was 6.4 which could be categorized under moderately acidic level (Herrera, 2005).

Experimental materials

The cultivar *Nantes* carrot seed was used as a test plant. The carrot seed was obtained from Damota Wolaita farmers union which is packed in France.

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Treatments and experimental design

Four rates of blended NPS (0, 50, 100 and 150 kg NPS ha^{-1} together with four rates of KCl (0, 71, 142 and 213 kg K ha^{-1}) fertilizers were arranged in factorial combination in a Randomized Complete Block Design (RCBD) with three replications and each treatment assigned at random to each experimental plot. Besides 100 kg ha^{-1} urea added to all experimental units.

Data analysis

All data were subjected to analysis of variance by using the general linear model of SAS statistical package version 9.4 (SAS, 2014). Significant treatment mean differences were separated using the LSD test at 0.05 probability level.

Results and discussion

Root characteristics of *Nantes* Carrot variety

The root length and core diameter of roots were significantly influenced by the application of NPS and KCl fertilizers. However, their interaction had a significant effect only on core diameter of roots. The longer roots of 15.17 and 15.53 cm were observed in plants that received 150 kg ha^{-1} NPS and 213 kg ha^{-1} KCl fertilizers, respectively. The application of 100 kg ha^{-1} NPS and 142 kg ha^{-1} KCl fertilizers followed by 50 kg ha^{-1} NPS and 71 kg ha^{-1} KCl fertilizers also produced longer roots than plants grown without application of the two fertilizers (Table 1). This variation might be due to the contribution of supplied nutrients on the growth of carrot plants including the increased number of leaves and height of plants that indirectly improve root length of the crop. The higher amount of potassium from higher rates of KCl fertilizer might also facilitate the transporting of assimilates into the carrot roots and increased the root size. This study is supported by Shikha et al. (2016) that clearly indicated similar finding.

Core diameter of root was significantly affected by interaction of NPS and KCl fertilizers. The wider root diameter of 4.86 cm was observed in plants that received combinations of 150 kg ha^{-1}NPS with 213 kg ha^{-1} KCl fertilizers. The application of 100 kg ha^{-1} NPS with 142 kg ha^{-1} KCl fertilizers resulted in the next wider root core diameter (Table 1). The root core diameter obtained by the application of 150 kg ha^{-1} NPS with 142 kg ha^{-1} KCl fertilizers, the application of 50 kg ha^{-1} NPS with 213 kg ha^{-1} KCl fertilizers and 0 kg ha^{-1} NPS with 213 kg ha^{-1} KCl were

statistically similar root width but, numerically they were different i.e 4.33, 4.43 and 4.20 cm, respectively. This finding is in agreement with Arega (2018) that reported high rates of blended NPS and potassium fertilizer application significantly increased the size and number of tubers produced per plant on potato.

The application of NPS and KCl fertilizers as well as their interaction had significant effects on cracked and branched roots, root fresh weight, and root dry matter content of *Nantes* carrot variety. The higher cracked and branched roots of 3 and 2.9 t ha^{-1} were found in plants that received 150 kg ha^{-1} NPS with 213 kg ha^{-1} KCl fertilizers, respectively. The application of 100 kg ha^{-1} NPS with 71 kg ha^{-1} KCl, 150 kg ha^{-1} NPS with 0 kg ha^{-1} KCl and 150 kg ha^{-1} NPS with 213 kg ha^{-1}KCl fertilizers treated carrot variety gave 2.86, 2.89 and 2.90 t ha^{-1} branched root, which they were statistically similar and higher than plants grown without application of the two fertilizers (Table 1).

The application of fertilizers at the rates of 0 kg ha^{-1} NPS with 213 kg ha^{-1} KCl, 50 kg ha^{-1} NPS with 0 kg ha^{-1} KCl, 50 kg ha^{-1} NPS with 142 kg ha^{-1} KCl, 100 kg ha^{-1} NPS with 0 kg ha^{-1} KCl, 100 kg ha^{-1} NPS with 142 kg ha^{-1} KCl, 100 kg ha^{-1} NPS with 213 kg ha^{-1} KCl, and 150 kg ha^{-1} NPS with 71 kg ha^{-1} KCl gave 1.33, 1.33, 1.33, 1.43, 1.36,1.33, 1.43 t ha^{-1} in terms of the cracked roots respectively, and they were statistically not different. While, in terms of branched roots, above mentioned treatment rates were statistically varied. Increased rates of the integrated application of two fertilizers increased branched roots higher than that of cracked ones. This result agrees with the findings of Malik et al. (2003). Nesa (2007) documented that the highest cracked and branched roots were found from the N_{98} P_{72} $K_{87}S_{14}$kg $ha^{-1}$and lowest from the control.

The higher root fresh weight and root dry matter content of 121.7 g followed by 116 g and 10.33% followed by 10.23% were got in plants that received 150 kg ha^{-1} NPS with 213 kg ha^{-1} KCl fertilizers and 150 kg ha^{-1} NPS with 142 kg ha^{-1} KCl fertilizers, respectively. The application of 0 kg ha^{-1} NPS with 213 kg ha^{-1} KCl, 50 kg ha^{-1} NPS with 213 kg ha^{-1} KCl, 100 kg ha^{-1} NPS with 71 kg ha^{-1} KCl and 100 kg ha^{-1} NPS with 142 kg ha^{-1} KCl fertilizers treated carrot variety gave 89.40, 87.07, 89.63 and 83.5 g of root fresh weight which were statistically similar and higher than plants grown without application of the two fertilizers (Table 1).

The application of 50 kg ha^{-1} NPS with 0 kg ha^{-1} KCl,150 kg ha^{-1} NPS with 0 kg ha^{-1} KCl, 50 kg ha^{-1} NPS with 213 kg ha^{-1} KCl, 50 kg ha^{-1} NPS with 142 kg ha^{-1} KCl, 0 kg ha^{-1} NPS with 142 kg

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ha^{-1} KCl and 100 kg ha^{-1} NPS with 0 kg ha^{-1}KCl fertilizers treated carrot variety gave 7.18, 7.00, 6.96, 6.86, 6.66 and 6.66 % of root dry matter contents, respectively. They were statistically similar and higher than plants grown without the application of the two fertilizers.

Table 1. Interaction effect of NPS and KCl fertilizers on carrot root characteristics at Waja Kero during 2019 cropping season.

Treatment		Root characteristics				
NPS (kg ha^{-1})	KCl (kg ha^{-1})	Root core diameter (cm)	Cracked roots(t ha^{-1})	Branched roots (t ha^{-1})	Root fresh weight (g)	Root dry matter (%)
0	0	2.36^{g}	1.16^{de}	0.83^{f}	58^{g}	5.76e
0	71	2.41^{g}	1.08^{e}	1.36^{cdef}	72.43^{ef}	6.15^{de}
0	142	2.56^{fg}	1.20^{de}	1.10^{ef}	71.30^{fg}	6.66^{cde}
0	213	4.20^{abc}	1.33^{cde}	1.16^{def}	89.40^{bc}	7.33^{bcd}
50	0	2.72^{efg}	1.33^{cde}	2.18^{b}	72.80^{def}	7.18^{cde}
50	71	3^{efg}	1.81^{c}	1.83^{bc}	80.10^{cdef}	6.23^{de}
50	142	2.58^{fg}	1.33^{cde}	1.76^{bcd}	85.30^{bcde}	6.86^{cde}
50	213	4.43^{abc}	1.06e	0.95^{f}	87.07^{bc}	6.96^{cde}
100	0	2.57^{fg}	1.43^{cde}	1.71^{bcde}	83.37^{dcdef}	6.66^{cde}
100	71	3.33^{de}	2.46^{b}	2.86^{a}	89.63^{bc}	7.50^{bcd}
100	142	4.60^{ab}	1.36^{cde}	1.68^{bcde}	89.50^{bc}	7.46^{bcd}
100	213	4.10^{bc}	1.33^{cde}	1.80^{bc}	94.33^{b}	8.66^{b}
150	0	3.22^{def}	1.78^{c}	2.89^{a}	82.13^{bcd}	7.00^{cde}
150	71	3.77^{cd}	1.43^{cde}	1.81^{bc}	86.50^{bcd}	7.90^{bc}
150	142	4.33^{abc}	1.68^{cd}	2.16^{b}	116.60^{a}	10.23^{a}
150	213	4.86^{a}	3^{a}	2.90^{a}	121.70^{a}	10.33^{a}
LSD (0.05)		0.69	0.26	0.61	13.85	0.71

Mean values bearing the common letter(s) in a column did not differ significantly at 5% level of probability, and LSD (0.05) = Least Significant Difference at $P \leq 0.05$.

The present finding is in agreement with Kumar et al. (2015), who stated continuous increasing of potassium enhanced root fresh weight of carrot due to the prominent role of Potassium in translocation of photo assimilates, sugars and other soluble solids to the root. Similarly, Abraha

et al. (2015) reported sulfur and nitrogen in NPS fertilizer stimulate the enzymatic actions and chlorophyll formations which contribute to an increase in root size and consequently plot received high NPS produced maximum root fresh weight.

Carrot marketable, unmarketable and total root yield

The marketable and unmarketable root yields of *Nantes* carrot variety were significantly influenced by the application of NPS and KCl fertilizers as well as their interaction. The higher marketable and unmarketable root yields of 24.6 followed by 23.4 and 5.9 followed by 5.33 t ha^{-1} were found in plants that received 150 kg ha^{-1} NPS with 213 kg ha^{-1}KCl fertilizers and 150 kg ha^{-1} NPS with 142 kg ha^{-1}KCl fertilizers, respectively (Table 2). In contrast, carrot treated 0 kg ha^{-1} NPS with 142 kg ha^{-1}KCl and 0 kg ha^{-1} NPS with 213 kg ha^{-1}KCl gave marketable root yield of 10.9 and 10.86 ha^{-1} and statistically not different.

The application of 150 kg ha^{-1} NPS with 71 kg ha^{-1}KCl, 100 kg ha^{-1} NPS with 0 kg ha^{-1}KCl and 100 kg ha^{-1} NPS with 213 kg ha^{-1}KCl, 50 kg ha^{-1} NPS with 142 kg ha^{-1}KCl fertilizers supplied to *Nantes* variety gave 3.25, 3.14, 3.14 and 3.10 t ha^{-1} unmarketable root yield, respectively (Table 2). As finalizing remarks, the application of 150 kg ha^{-1} NPS with 213 kg ha^{-1}KCl and 150 kg ha^{-1} NPS with 142 kg ha^{-1}KCl gave about 173.33 and 160% in terms of marketable root yield and 201 and 172% increment on unmarketable root yield per hectare over plants grown without two fertilizer by marketable root and 50 kg ha^{-1} NPS with 213 kg ha^{-1}KCl supplied to plant by unmarketable root, respectively.

This might be due to the absence of adequate nutrient level needed for proper growth and development which contributed to the low marketable yield in the nil. This study is supported by Dagne (2015); Yesmin (2014) and Nesa (2007), who indicated that increased rates of macronutrients like Nitrogen, phosphorus, potassium and sulfur increased marketable root yield. Significant increases in carrot yields in response to increased phosphorus application due to high diffusion blockage (Nahar et al., 2014).

Total root yield was significantly influenced by the application of NPS and KCl fertilizers as well as their interaction. The higher total root yield of 30.5 t ha^{-1} was observed in plants that received 150 kg ha^{-1} NPS with 213 kg ha^{-1}KCl fertilizers. The increase of total root yield was linear from the 11 to 30.5 t ha^{-1}, when the rate of integrated NPS and Potassium fertilizer application rates increased from control to 150 kg ha^{-1} NPS with 213 kg ha^{-1}KCl (Table 2).

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Application of 100 kg ha^{-1} NPS with 71 kg ha^{-1}KCl and 150 kg ha^{-1} NPS with 71 kg ha^{-1}KCl gave about 24.09 and 23.31 t ha^{-1} of total root yield.

Gross root yield on this experiment showed about 177% increments by the application of 150 kg ha^{-1} NPS with 213 kg ha^{-1}KCl over the control. This might be due to the contributions of different types of nutrients in the blended NPS and Potassium enhanced the gross yield of this crop. NPS fertilizer is a cheap source of phosphorus (38%) which plays a vital role in the energy transfers in the cell. Similarly, Yesmin (2014) reported P and K fertilizer application significantly increased the root yield of the carrot.

Table 2. Interaction effect of NPS and KCl fertilizers on carrot root yields at Waja Kero during 2019 cropping season

Treatment		Root yields		
NPS (kg ha^{-1})	KCl (kg ha^{-1})	Marketable root yield (t ha^{-1})	Unmarketable root yield (t ha^{-1})	Total root yield (t ha^{-1})
0	0	9^{g}	2^{g}	11^{j}
0	71	9.9^{fg}	2.45^{g}	12.35^{ij}
0	142	10.9^{f}	2.3^{g}	13.16^{i}
0	213	10.86^{f}	2.5^{fg}	12.7^{i}
50	0	10^{fg}	3.51^{cde}	13.51^{hi}
50	71	11.33^{ef}	3.65^{cd}	14.98^{gh}
50	142	12.66^{de}	3.10^{de}	15.76^{g}
50	213	13.73^{d}	1.96^{g}	15.70^{g}
100	0	15.73^{c}	3.14^{de}	18.87^{f}
100	71	18.76^{b}	5.33^{a}	24.09^{cd}
100	142	19.36^{b}	3.05^{ef}	22.41^{e}
100	213	19.70^{b}	3.14^{de}	22.84^{de}
150	0	19.86^{b}	4.67^{b}	24.53^{c}
150	71	20.06^{b}	3.25^{de}	23.31^{cde}
150	142	23.40^{a}	3.85^{c}	27.25^{b}
150	213	24.60^{a}	5.90^{a}	30.50^{a}
LSD (0.05)		1.44	0.58	1.65

Mean values bearing the common letter(s) in a column did not differ significantly at 5% level of probability, and LSD (0.05) = Least Significant Difference at $P \leq 0.05$.

Partial budget analysis

The total net benefit from *Nantes* carrot variety production was in the range between 40313.74 Birr without application of the two fertilizers and 118881 Birr by application of 150 kg NPS ha^{-1}

and 213 kg KCl ha^{-1} fertilizers in combination. The higher total net benefit between 90485.4 and 118881 Birr obtained from 100 kg NPS ha^{-1} in combination with 71, 142 and 213 kg KCl ha^{-1} and 150 kg NPS ha^{-1} in combination with 71, 142 and 213 kg KCl ha^{-1} fertilizers (Table 3).

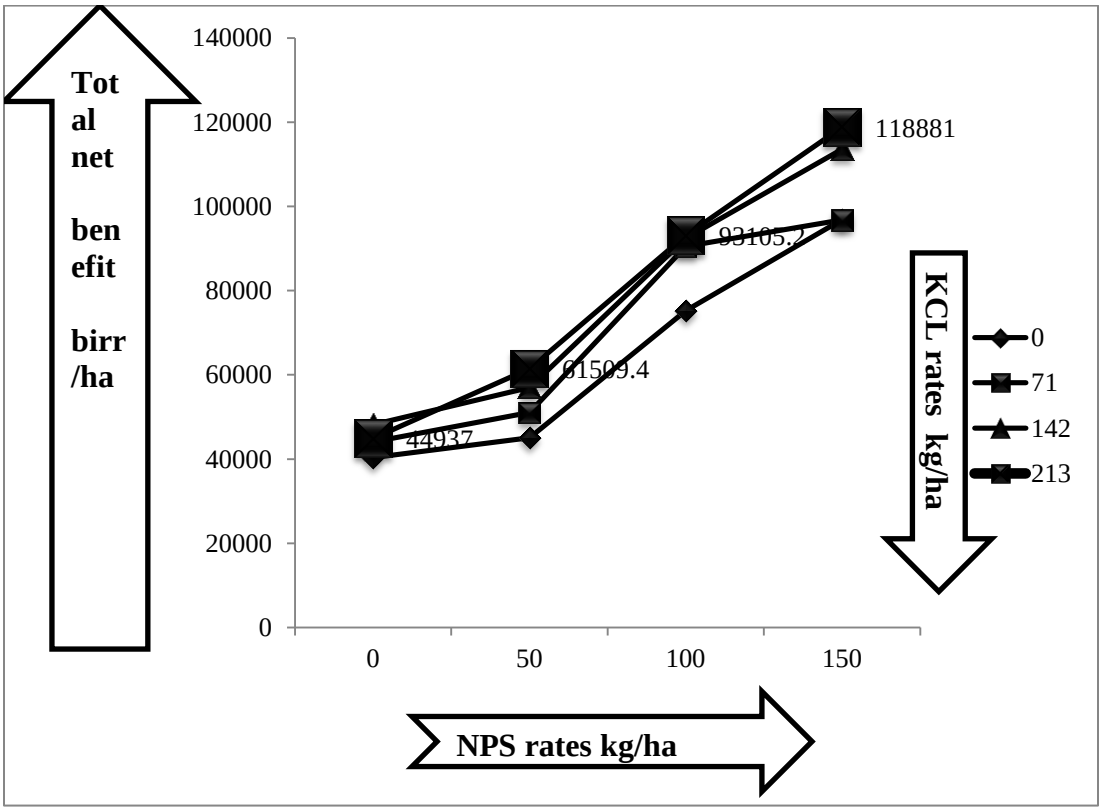

Figure 1. Total net benefit obtained from rates of NPS and KCl fertilizers for carrot production

The marginal rate of return (MRR %) was in the range between 127.71 and 2755.97%. The lowest and highest MRR (%) were obtained from the application of 213 kg KCl ha^{-1} without NPS fertilizer and the application of 150 kg NPS ha^{-1} without KCl fertilizer, respectively (Table 3). The MRR (%) was higher at the application of 150 and 100 kg NPS ha^{-1} in a combination of 0 and 71 kg KClha^{-1} fertilizer but the MRR (%) was reduced at the rates of KCl fertilizer increased beyond 71 kg ha^{-1} in a combination of all rates of NPS fertilizer. Therefore, the tentative recommendation of this reach was made that the combined application of 150 kg NPS ha^{-1} and 213 kg KCl ha^{-1}fertilizers. This treatment had had MRR (%) of 1385% above the minimum acceptable marginal rate of return but bear the highest total net benefit of 118881 Birr per hectare.

Table 3. Partial Budget Analysis for NPS and KCl fertilizers on *Nantes* carrot at Waja Kero during 2019 cropping season.

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NPS (kg/ha)	KCl (kg/ha)	UnMyld (t ha^{-1})	AdjMyld (t ha^{-1})	TVC (ETB)	GR (ETB)	NB (ETB)	MRR absolute	MRR (%)
0	0	9	8.1	8286.26	48600	40313.74		
0	71	9.9	8.91	9426.26	53460	44033.74	3.26	326.32
0	142	10.9	9.81	10706.3	58860	48153.7	3.24	323.96
0	213	10.86	9.77	11906.4	58620	44937	1.28	127.71
50	0	10	9	8970.46	54000	45029.54	6.89	689.24
50	71	11.33	10.19	10110.4	61140	51029.6	5.87	587.45
50	142	12.667	11.4	11390.5	68400	57009.5	5.38	537.84
50	213	13.733	12.35	12590.6	74100	61509.4	4.92	492.43
100	0	15.733	14.15	9654.67	84900	75245.33	25.53	2552.71
100	71	18.766	16.88	10794.6	101280	90485.4	20.00	2000.19
100	142	19.366	17.42	12074.7	104520	92445.3	13.76	1376.07
100	213	19.7	17.73	13274.8	106380	93105.2	10.58	1058.25
150	0	19.866	17.87	10338.8	107220	96881.2	27.56	2755.97
150	71	20.066	18.05	11478.8	108300	96821.2	17.70	1769.98
150	142	23.4	21.06	12758.9	126360	113601.1	16.39	1638.57
150	213	24.6	22.14	13959	132840	118881	13.85	1385.00

Price of blended NPS fertilizer cost = Birr 13.68 kg^{-1-}, KCl fertilizer cost = Birr 14.08 kg^{-1}, Unit price of 1kg carrot seed=1600 birr (Source: 2019/20 Wolaita Damota farmers' Cooperative Union *Meher* season agricultural input tentative price report and Wolaita zone Finance and Economy Development Office). UuMyld =unadjusted Marketable root yield, AdjMyld =adjusted Marketable root yield, Field price of carrot during harvesting = Birr 6 kg^{-1}, TVC (ETB) = total variable cost, GR (ETB) = gross farm return, NB (ETB) = net benefit in Birr, MRR and MRR (%) = absolute and percentage marginal rate of return, respectively.

Conclusions

Carrot is an important root vegetable crop in Ethiopia that could have a significant contribution to tackle chronic Vit A malnutrition and could be one of export commodities to generate foreign currency earnings and income generators for resource poor farmers. The absence of recommendations for the rates of blended NPS and potassium fertilizers for carrot production is

one of the major constraints to increase the yield of the crop. Therefore, this research was initiated to assess the response of *Nantes* carrot variety to blended NPS and KCl fertilizers rates and estimate the cost-benefit for the rates of NPS and KCl fertilizers for carrot production to mitigate carrot production challenge of Sodo Zuria, Woreda of Wolaita Administration Zone.

The performance of *Nantes* commercial carrot variety for growth, root characteristics and root yield components was better due to the application of NPS and KCl fertilizers at higher rates than the variety was grown without the application of the two fertilizers and to the application of the two fertilizers at lower rates. The highest marketable root yield 24.6 t ha^{-1} was obtained by the application of 150 kg ha^{-1} NPS and 213 kg ha^{-1}KCl fertilizers followed by 23.4 and 20.07 t ha^{-1} marketable root yield obtained by the application of 142 and 71 kg ha^{-1}KCl fertilizer, respectively, in combination with 150 kg ha^{-1} NPS fertilizer.

The combined application of 150 kg ha^{-1} NPS and 213 kg ha^{-1}KCl fertilizers bear the highest total net benefit of 118881 Birr per hectare with MRR of 1385% which was above the minimum acceptable range. Further research is also needed in conducting replicated evaluation of the treatments and carrot variety over varied locations and seasons in the Woreda.

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