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Response of Medium and Late Maturing Sweetpotato (Ipomoea batatas L.) Varieties to Application of N and P Fertilizers in Halaba Area of Southern Ethiopia

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Abstract
A two-year field study was conducted during the growing seasons of 2013 and 2014 in Halaba, southern Ethiopia to evaluate the response of two improved sweetpotato varieties (Kulfo and Awassa-83) to four rates of N and three rates of P_2O_5. Factorial combinations of the treatments were arranged into a randomized complete block design with three replications. Results showed that averaged over P_2O_5 and Nitrogen rates, Awassa-83 (late maturing and white fleshed) had longer vines (longer by 47 cm) than Kulfo variety (medium maturing and orange fleshed). However, Kulfo variety had significantly higher ($p<0.05$) branches than Awassa-83. Increment in phosphorus levels from 0 to 92 P_2O_5 did not result in significant ($P<0.05$) variation in root length, root width, number of roots/plant, number of branches/plant and root yield/unit area. In fact, most sweetpotatoes growth and yield components responded significantly ($P<0.05$) to application of nitrogen, and the two varieties responded differently to its application. Significantly higher ($P<0.01$) root yield of Awassa-83 variety was obtained due to application of 46 kg/ha P_2O_5 and 92 kg/ha N. Similarly, significantly higher ($P<0.01$) root yield of Kulfo variety was obtained with the application of 92 kg/ha P_2O_5 and 92 kg/ha N. However, root yield of Kulfo variety due to 46 kg/ha P_2O_5 and 92 kg/ha N, and 46 kg/ha P_2O_5 and 46 kg/ha N were not significantly different ($p<0.05$). Moreover, economic analysis depicted that fertilizer rates that produced agronomic optimum have also resulted in highest marginal rate of return. Hence application of 46 kg/ha P_2O_5 and 46 kg/ha N would be agronomic and economic optimum for Kulfo variety production in Halaba areas, and other warm sub moist lowlands of the country with similar soil types and soil fertility status. It can be concluded that the response of white and orange fleshed medium and late maturing varieties were different to application of chemical fertilizers within a given locality.
Keywords: Maturity groups, Nitrogen, Phosphorus, Vine length, Root yield

1. Introduction

Sweetpotato (*Ipomoea batatas* L. Lam.) is a herbaceous viny root crop native to the tropics and requires warm days and nights for optimum growth and root development. It belongs to family *Convovulaceae*. The crop is perennial plant grown as annual upon cultivation. The plant can have 1 to 5m long stem (depending on environment and variety), 3 to 10 mm stem thickness, and 12 to 20 cm inter-node length and can produce 5 to 10 storage roots per plant. The crop can reproduce from vine cuttings, sprouts of storage roots and from true seeds depending on environment, purpose of production and variety. So the selection and care of sweetpotato roots for production of slips and vine cuttings are probably the most important practices in profitable sweetpotato production.

Sweetpotatoes are fairly tolerant of variations in soil pH between 5.2 and 6.7. However, the optimum soil pH for high yields of quality sweetpotatoes is 5.8 to 6.0. Hence, application of lime is required in soils of very low pH. A sweet potato crop producing on e ton of yield depletes about 110 N, 15 P, and 150 K from the soil. Therefore application of soil test based nutrients is required to return the harvested nutrients and sustain crop production. On very sandy soils where leaching of nitrogen may occur, it is best to use a split application of N. In this case, 20 pounds would be applied pre-plant and incorporated into the soil with the second application coming four to five weeks after transplanting into the field. When transplanting, a starter solution high in phosphorus should be applied at a rate of one-half point of solution per plant (Moyo, *et al,* 2013). A study carried out in Adami tulu areas of Ethiopia using *Belela* variety recommended application of 20 t farmyard manure ha-1 and 180 kg ha-1 P2O5 resulted in production of highest marketable yield (32.56 tha^{-1}) (Teshome, 2012). In another study carried out in Delbo wogene (southern Ethiopia), the highest root yield (24.12t/ha) was achieved using 46kg/ha N and 5t/ha FYM (Daniel and Gobeze, 2016).

To date, the effect of climate change has become profound in each and every corner of the globe. Crops are suffering from increased droughts in some areas. There are also increased flood, pest and disease occurrence in other areas and times. The immediate effects were causing serious soil erosion and huge emission of green house gases, making significant shift in rainfall pattern besides leading to decline in available water in tropics. However, these have resulted in dramatic shift in strategic choice of crop commodities where root and tuber crops like sweetpotato, cassava, taro, and the like came into picture as food security crops in Africa in general and in Ethiopia in particular. Some of the crop management options that boost sweetpotato yields during such scenarios were use of appropriate cultural practices like planting dates, plant densities, soil fertility, watering frequency and amount of irrigation water.

In many African countries, sweet potato was grown using NPK fertilizers (Moyo, *et al*, 2013; Okpara., *et al*, 2009). In Ethiopia, commercial vine multipliers employed large quantity of urea and diammonum phosphate to achieve healthy vigorous plants and robust yields. In the later case, the amount of fertilizer applied varied from one location to other and with frequency of cuttings. Traditional sweet potato growers have employed use of organic fertilizers like farm yard manure, compost and other house wastes in their sweet potato gardens. However, the amount of fertilizer required to produce optimum number vine cuttings per unit area and also to produce optimum sweet potato root yields were not determined until recently. Despite the increased demands for sweetpotato cuttings, the appropriate management practices that maximize the vine and root yield of sweetpotato were not identified under growing conditions of Halaba until recently. Hence this experiment was carried out to determine appropriate level of N and P fertilizers that maximize root and vine yield of sweetpotatoes.

2. Materials and methods

The experiment was carried out in Halaba (SM2 – warm sub moist lowlands), southern Nations and Nationalities region of Ethiopia 310 km south of Addis Ababa and about 85 km south west of the Regional capital, Awassa in the Great Ethiopian Rift Valley. The experiment consisted of two sweet potato varieties namely Awassa-83 (white fleshed) and Kulfo (Orange fleshed), four levels of Nitrogen (N) including 0, 46, 92, 138 kg/ha and three levels of phosphorus (P_2O_5): 0, 46, 92 kg/ha using the randomized complete block design with 2x3x4 factorial arrangement of fertilizer rates in sub plots and test varieties in main plots, with three replications. Fertilizer application was done in such a way that urea fertilizer was applied in two splits i.e 50% at planting and 50% of it at 45 days after planting where as phosphorus fertilizer was applied all at once during planting. Triple Super Phosphate (TSP) was used in control plots where no nitrogen is required. Composite soil sample prior planting was collected and analyzed. Data on average vine length, vine number per plant and per plot, root yield/plant, root yield/m^2 and number of roots/plant was gathered, and later converted to per hectare basis. Number of vines per hectare was calculated as Results were analyzed using SAS version 9 and means were separated by LSD at 1 and 5% of probability.

3. Results and discussions

3.1 Soil characteristics of the study area

The chemical and physical properties of the top 30 cm soils at the experimental sites were analyzed to determine the characteristics of soils in the study area. Accordingly, Halaba testing site is located in 1650m *a.s.l* with pH water (1:2.5) 6.6, EC (ds/m)=0.050, CEC me/100g soil =15.1, total N=0.094, avail P (ppm)=5.6, available K (ppm) = 86.2, OC (%) = 1.9 with sandy clay loam texture. Thus N and P are low while organic matter levels are medium.

$$\text{Number of vines/ha} = \frac{10^4 * \text{average vine length (cm)} * \text{No of vines/plant}}{\text{Size of single vine used for planting (eg. 30cm)}}$$

3.2 Main effects of variety, phosphorus and nitrogen levels

3.2.1 Effects of sweetpotato varieties on growth and yield components

The two varieties, Awassa-83 and Kulfo, were dominant in the production system in southern Ethiopia. However, Awassa-83 variety is late maturing (5 months) and white fleshed where as Kulfo is early maturing (four months) and orange fleshed. Averaged over P_2O_5 and Nitrogen rates, Awassa-83 had longer vines (longer by 47 cm) than *kulfo* variety where as Kulfo variety had significantly higher branches than Awassa-83. A single vine of Awassa-83 is 143.1cm long. This means that it could be cut in to four thirty to forty cm long vines for planting. However, *kulfo* variety may be cut in to two to three vines for planting. Thus in a hectare of land about 5,000,000 and 4,000,000 vines could be produced in four to five months in Awassa-83 and Kulfo variety (Table1).

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Table 1. Main effects of sweetpotato varieties, phosphorus and nitrogen levels

Variety	Root length (cm)	Root width (cm)	Roots number/ plant	Root weight/ plant (kg)	Vine length (cm)	Branches number/ plant	Root yield (kg/m2)
Awassa-83	32.0	44.3	3.97	0.78	143.1	22.4	39.1
Kulfo	36.0	42.3	3.86	0.61	96.1	27.5	34.9
LSD (%)	NS	NS	NS	NS	23.4*	4.8*	NS
P2O5							
0	32.9	42.1	4.03	0.64	88.5	23.7	34.6
46	32.8	44.5	4.01	0.87	167.8	24.3	40.2
92	32.8	43.3	3.71	0.57	102.6	26.8	36.3
LSD (%)	NS	NS	NS	0.25*	28.4*	NS	NS
N							
0	28.8	38.3	2.68	0.57	78.8	20.7	25.2
46	34.1	47.7	3.77	0.84	181.8	30.4	38.6
92	34.3	48.0	5.32	0.68	110.4	30.2	49.4
138	34.1	39.2	3.90	0.68	107.4	18.6	34.9
LSD (%)	NS	6.1*	1.32*	NS	43.4*	8.1**	7.3**
CV (%)	27.1	20.6	51.4	61.7	43.0	48.1	29.1

*LSD stands for least significance difference, CV means coefficient of variation, *, **, shows significance at 5 and 1% level of probability. ns denotes absence of statistical difference at 5% level of probability.*

3.2.2 Effects of phosphorus on growth and yield components

When averaged over varieties and nitrogen levels, increment in phosphorus levels from 0 to 92 P_2O_5 did not result in significant ($P<0.05$) variation in root length, root width, number of roots/plant, number of branches/plant and root yield/unit area. However, the main effects of phosphorus was significant ($P<0.05$) on vine length and root weight/plant. Results showed that increment in P_2O_5 from 0 to 46 resulted in 36% increment in root weight/plant. However as P_2O_5 was increased from 46 to 92 kg/ha, there was decrease in root weight/plant by 34%. Similarly, increment of P_2O_5 application from 0 to 46 kg/ha P_2O_5 resulted in 47% increase in vine length. Further increase of P_2O_5 application from 46 to 92 kg/ha resulted in 39 % decrease in vine length (Table1). The response curve drawn against P_2O_5 also showed gradual increase in root bulking as rates of phosphorus was increased. Then it reached pick of root bulking at 46 kg/ha P_2O_5 for both *Awassa*-83 and *Kulfo* varieties and declined there after (Fig 1)

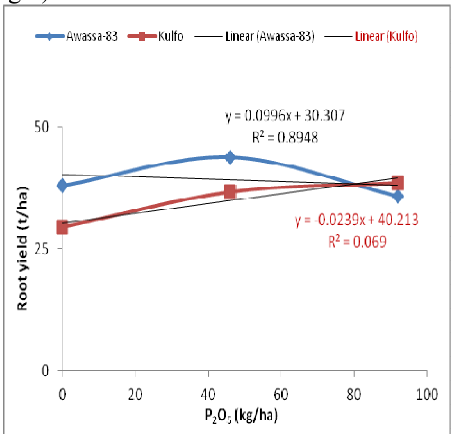

Fig 1. Response of root yield to effects of P2O5

3.2.3 Effects of nitrogen on growth and yield components

When averaged over varieties and P_2O_5, the effect of nitrogen was significant ($P<0.05$) on most growth and yield components except root length and root weight/plant. Significantly higher root yield, root width (cm), roots number/ plant and branches number/ plant was obtained due to application of 92 kg/ha N compared to other levels of nitrogen treatment (Table1). The response curve drawn against N also shows pick of root bulking at 92 and 46 kg/ha N for *Awassa*-83 and *Kulfo* varieties, respectively (Fig 2). The higher rates of nitrogen obtained with this study agreed with research work of S. B. Yengl and his fellows that recommended integrated combinations of 150 kg NPK ha-1 + 1.5 t/ha chicken manure and 100 kg NPK ha-1 + 3.0 t/ha chicken manure for sweet potato production in the Guinea savanna and forest-savanna transition zones Nigeria. However, the lower rates of P were against the findings of S.B. Yengels and his work mates, (S.B Yengel *et al*., 2012).

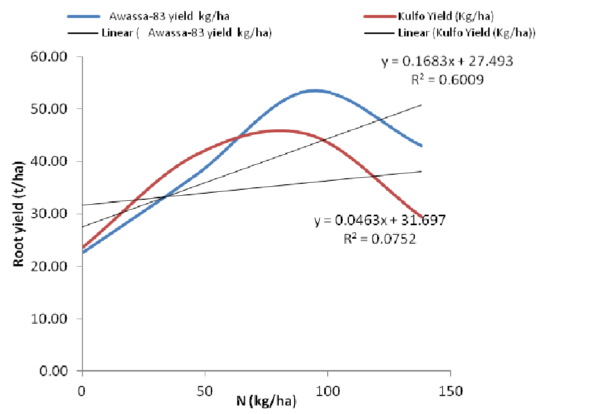

Fig 1. Response of root yield (t/ha) to applied N

3.3 Interaction effects

3.3.1 Two way interaction effects of variety x phosphorus, variety x nitrogen and nitrogen x Phosphorus

There was not significant ($p<0.05$) any two way interaction among variety x phosphorus, variety x nitrogen and nitrogen x phosphorus for root length, number of roots/plant, weight of roots/plant and vine length. However, there was significant ($p<0.05$) any two way interaction variety x phosphorus, variety x nitrogen and nitrogen x phosphorus for growth and yield components namely root width, number of branches and root yield (Table 2).

Significantly higher number of branches were obtained due to application of 92 kg/ha P_2O_5 in kulfo variety. Least number of branches was obtained due to Awassa -83 variety when no fertilizer was applied. The root width due to application of 92 kg/ha P_2O_5 in *kulfo* variety and 46 kg/ha P_2O_5 in Awassa-83 variety was significantly higher other levels of variety x P_2O_5 application levels. When averaged over nitrogen levels, application of 46 kg/ha P_2O_5 in Awassa-83 variety produced significantly higher root yield i.e 43.6t/ha. In *kulfo* variety, application of 92 kg/ha P_2O_5 produced 38.5t/ha. There was increment in root yield as there was increment in nitrogen level in both early and late maturing varieties. When averaged over P_2O_5 levels, 92 kg/ha N produced significantly higher root yield in Awassa-95 variety with yield nearing 53.5t/ha. Similarly 92 kg/ha N produced significantly higher root yield in *kulfo* variety with yield nearing 45.2t/ha. In both varieties significantly lower yield were measured due to no fertilizer application (Table 2). This finding agrees with that of Teshome (2012) who obtained optimum marketable yield (32.04 t ha-1) due to combined application of 10 t FYM ha-1 and 180 kg P_2O_5 ha-1 in Adami tulu area of Ethiopia.

Table 2. Two way interaction effect of variety x phosphorus, and variety x nitrogen on root width, number of branches and root yield of sweetpotato

Varieties	**Phosphorus (P_2O_5) (kg/ha)**									**Nitrogen (kg/ha)**			
	Number of branches			**root width (cm)**			**root yield(kg/m2)**			**root yield(kg/m2)**			
	0	46	92	0	46	92	0	46	92	0	46	92	138
Awassa-83	18.4	26.3	22.6	29.3	35.1	31.7	39.8	43.6	33.9	24.1	35.9	53.5	43
Kulfo	29.2	22.4	31	30.7	33.8	36.4	29.4	36.7	38.5	26.3	41.3	45.2	26.9
LSD (5%)	**9.6**			**4.2**			**8.6**			**99**			

*LSD stands for least significance difference, CV means coefficient of variation, *, **, shows significance at 5 and 1% level of probability. ns denotes absence of statistical difference at 5% level of probability.*

3.3.2 Three way interaction effects of variety x N X P_2O_5

Significantly higher ($P<0.01$) root yield of Awassa-83 variety (white fleshed) was obtained due to application of 46 kg/ha P_2O_5 and 92 kg/ha N in Awassa-83 variety. There was dramatic linear increment due to increment in nitrogen compared to phosphorus applications (Table 3). Similarly, significantly higher ($P<0.01$) root yield of Kulfo variety (orange fleshed) was obtained due to application of 92 kg/ha P_2O_5 and 92 kg/ha N. However, root yield of *kulfo* variety due to 46 kg/ha P_2O_5 and 92 kg/ha and 46 kg/ha P_2O_5 and 46 kg/ha N were statistically invariable. Hence application of 46 kg/ha P_2O_5 and 46 kg/ha N would be agronomic optimum for *kulfo* variety production in Halaba area (Table 3). These findings are in line with Okpara and his colleagues who found that nitrogen application up to 120 kg N ha increased light interception; leaf area index and shoot dry matter in Nigeria. The storage root yield increased with N application up to 80 kg N ha when the background soil N was 0.056%. The white-fleshed TIS 87/0087 followed by orange-fleshed Ex-Igbariam out-yielded other varieties and intercepted over 70% of the incident radiation (D A Okpara, *et al*., 2009).

Table 3. Three way interaction effects of variety x phosphorus x nitrogen on root yield (t/ha) of orange and white fleshed sweetpotato in Halaba

	Awassa-83			Kulfo		
Nitrogen	Phosphorus levels (P2O5)					
	0	46	92	0	46	92
0	21.4	21.9	24.4	18.9	23.6	28.5
46	44.4	38.9	28.8	35.8	47.7	40.3
92	51.0	71.4	38.1	34.4	44.1	57.0
138	34.7	42.9	51.4	28.5	31.4	28.5
LSD (%)	17.8**					
CV (%)	29.1					

*LSD stands for least significance difference, CV means coefficient of variation, *, **, shows significance at 5 and 1% level of probability. ns denotes absence of statistical difference at 5% level of probability.*

This research result is against the findings in Chitedze (sandy clay loams), Chitala (sandy clay loams) and Makoka (clay loams) research stations of Malawi where fertilizer application did not significantly affect the sweetpotato root yield except at Makoka where the yields were significantly ($P<0.001$) increased by 23.0 and 29.7 % with 30 kg N and 60 kg N /ha, respectively. Nonetheless; it was not economically justifiable to apply more than 30 kg N /ha even at Makoka and the eating qualities of the boiled roots were not affected by fertilizer application in all sites (C.C Moyo *et al.,* 2013).

3.4 Economic analysis

3.4.1 Marginal rate of return and sensitivity analysis

A number of P2O5/N combinations that produced agronomical superior yield performance. Among these the following six treatments (0/92, 46/92, 92/138, 46/46 and 92/92 kgha^{-1} P_2O_5/N) were compared economically with unfertilized plots (0/0) using CIMMYT partial budget analysis procedures (CIMMYT, 1988). The treatment combination with 92/138kg/ha P_2O_5/N were dominated by preceding treatment combinations in Awassa-83 variety where as the rest two treatment combinations were economically viable compared to unfertilized plots as they produced marginal rate of return far above acceptable range (100%) (Table 5). When it comes to Kulfo variety, the treatment combination 46/92 and 92/46 P_2O_5/N were dominated by preceding treatment combinations where as the rest two treatment combinations were economically viable compared to unfertilized plots as they produced marginal rate of return far above acceptable range (100%) (Table 5). Despite higher yield and net economic benefit in other treatments, treatment with 46/92 kgha^{-1} P_2O_5/N produced the highest MRR of 6564% for Awassa-83 variety. Similarly, 46/46 P_2O_5/N produced the highest MRR of 5129 in *Kulfo* variety despite higher yield and net economic benefits in other treatment combinations. For each 1 birr investment for fertilizer application in Awasa-83 farm, a farmer would expect the recovery of his 1 Birr investment plus additional return of 65.64 Br. Similarly for each 1 birr invested in fertilizer application in growing *kulfo* variety, the farmer can recover his 1 birr plus additional return of 51.29 Br. The benefit could increase further as the vine cuttings could be sold for planting or for feeding cattle with reasonable price at times when the need arise.

Table 4. Partial budget analysis of selected P_2O_5/N treatment combinations

Varieties	Awasa-83				Kulfo			
Fertilizer combinations	0,0	0,92	46,92	92,138	0,0	46,46	46,92	92,46
Average yield, t/ha	21.4	51	71.4	51.4	18.9	47.7	44.1	40.3
Adjusted Yield, t/ha[1]	19.26	45.9	64.26	46.26	17.01	42.93	39.69	36.27
Field benefit, 103Br/ha[2]	96,300	229,500	321,300	231,300	85,050	214,650	198,450	181,350
Cost of fertilizer, Br/ha[3]	0	2202	3579.48	6057.96	0	2478.48	3579.48	3855.96
Cost of labor, Br/ha[3]	0	200	200	200	0	200	200	200
Total variable cost, Br/ha[3]	0	2402	3779.48	6257.96	0	2678.48	3779.48	4055.96
Net benefit, Br/ha	96,300	227,098	317,521	225,042	85,050	211,972	194,671	177,294
MRR (%)		5445	6564	D		5129	D	D

[1]*Yield adjusted downwards by 10% to reflect moisture loss during transportation and marketing*
[2]*In 2014, 100 kg of DAP and Urea was sold for 1377.48 Br and 1101 Br, respectively inclusive of cost of transportation*
[3]*A kilo of sweet potato was sold for 5birr on average*

3.4.2 Sensitivity analysis

Sensitivity analysis of profitability of fertilizer use relative to 20% increase in fertilizer price remained feasible based on the partial budget analysis (Table 6). Similarly it remained profitable upon 10% yield decrement due to moisture loss during transportation and sales (Table 5). In both cases and varieties, MRR were above the acceptable range. This depicts relative advantage and stability of economic benefits due to fertilizer use in the production of Sweet potato varieties named *kulfo* and *Awassa*-83 in Halaba and other areas of similar soil and climatic conditions. For each 1 birr investment for fertilizer application in Awasa-83 farm, a farmer would expected the recovery of his 1 Birr investment plus additional return of 54.53 Br. Similarly for each 1 birr invested in fertilizer application in growing *kulfo* variety, the farmer can recover his 1 birr plus additional return of 39.32 Br. However, this cannot be a net profit as there are additional costs that the farmer incurs for all treatments. These include costs of input and labor in land preparation, seedling/cutting purchase, cultivation and harvesting. However, technologies with higher MRR are more profitable compared to technologies with lesser MRR.

Table 6. Sensitivity analysis of selected P_2O_5/N treatment combinations in sweet potato var Kulfo and Awassa-83 (when fertilizer price was inflated by 20%)

Description	**Awasa-83**				**Kulfo**			
Fertilizer combinations	0,0	0,92	46,92	92, 138	0,0	46,46	46,92	92,46
Field benefit, 10^3Br/ha								
Old fertilizer price, Br/ha	96300	229500	321300	231300	85050	214650	198450	181350
New fertilizer price, Br/ha	96300	229500	321300	231300	85050	214650	198450	181350
Total variable cost, Br/ha								
Old fertilizer price, Br/ha	0	2402	3779.48	6257.96	0	2678.48	3779.48	4055.96
New fertilizer price, Br/ha	0	2882.4	4535.376	7509.55	0	3214.18	4535.37	4867.152
Net benefit, Br/ha								
Old fertilizer price, Br/ha	96300	229500	321300	231300	85050	214650	198450	181350
New fertilizer price, Br/ha	96300	226617.6	316764.6	223790.4	85050	211435.8	193914.6	176482.8
MRR(%)		4521	5453	D		3932	D	D

3.5 Association of traits

3.5.1 Awassa-83 variety

There was strong positive association among Awassa-83 variety mean root length and root width ($R2 = 0.653$, $p< 0.0001$), root width and root number ($R2 = 0.232$, $p< 0.001$), root width and branch number ($R2 = 0.522$, $p< 0.0001$), root width and root yield ($R2 = 0.566$, $p< 0.0001$), root length and vine length ($R2 = 0.653$, $p< 0.001$), root length and number of branches ($R2 = 0.643$, $p< 0.0001$), root number and root yield ($R2 = 0.795$, $p< 0.0001$).

Table 4. Correlation analysis among growth and yield components of sweetpotato (n=144)

Awassa-83							
	Root width	Root length	Root number	Root weight	Vine length	Branches number	Root yield
Root width	1.000						
Root length	0.653 ***	1.000					
Root number	0.232**	0.073ns	1.000				
Root weight	-0.186ns	0.119ns	0.026 ns	1.000			
Vine length	-0.166 ns	0.288**	0.030 ns	-0.175 ns	1.000		
Branches number	0.522***	0.643***	-0.025 ns	0.053 ns	-0.025ns	1.000	
Root yield	0.566***	0.137 ns	0.795***	-0.065ns	-0.106ns	0.146 ns	1.000
Kulfo							
	Root width	Root length	Root number	Root weight	Vine length	Branches number	Root yield
Root width	1.000						
Root length	0.844***	1.000					
Root number	-0.275 **	-0.029ns	1.000				
Root weight	-0.148 ns	-0.344**	-0.063 ns	1.000			
Vine length	0.146 ns	0.204ns	0.016ns	-0.575***	1.000		
Branches number	0.256 **	0.490 ***	0.034ns	0.004ns	0.159ns	1.000	
Root yield	-0.124	0.263**	0.606***	-0.330 **	0.264 **	0.347 **	1.000

*, **, *** - shows significance at 5, 1 and 0.1% level of probability. ns denotes absence of statistical difference at 0.1% level of probability.

3.5.2 Kulfo Variety

There was strong positive correlation among mean of Kulfo variety root length and root width (R^2 = 0.844, p< 0.0001), root width and branches number (R^2 = 0.256, p< 0.01), root length and branches number (R^2 = 0.490, p< 0.001), root length and root yield(R^2 = 0.263, p< 0.01), root number and root yield (R^2 = 0.606, p< 0.001), vine length and root yield (R^2 = 0.264, p< 0.01), branches number and root yield (R2 = 0.347, p< 0.001). Conversely, the association between root width and root number (R2 = -0.275, p< 0.01), root length and root weight (R^2 =-0.344, p< 0.001), vine length and root weight (R^2 = -0.575, p< 0.0001), root weight/plant and root weight/unit area (R^2 = -0.330, p< 0.01) was strong and negative in *kulfo* variety. Thus in *kulfo* variety, larger roots were also longer, larger and longer roots come from plants with more branches, higher yields were associated with longer roots, greater root number, taller vines and more number of branches. Strong negative associations among observe traits manifests that plants with more number of roots had smaller size, longer roots had smaller root weight, taller vines lead to smaller root weight/plant and subsequently lower yield/unit area in *kulfo* variety . The yield components of *kulfo* variety were associated to higher root length, root number, vine length and branches number where as awassa-83 were directly correlated with root number and root width. The variation of association behavior among varieties was attributed to variation in maturity groups, root shape and growth characters.

4. Conclusions

Sweet potato contributes significantly to human food availability in many parts of Ethiopia. In fact, Ethiopia is endowed with climatic and edaphic resources that favor the biological and economic yield of sweet potato. However, fertilizer regimes were not determined for sweet potato production in Halaba area of Southern Ethiopia until this two year study was carried out. The study revealed that application of 46 kg/ha P_2O_5 and 46 kg/ha N would be agronomic and economic optimum for *kulfo* variety production in Halaba area. Moreover, 46 kg/ha P_2O_5 and 92 kg/ha N would be agronomic and economic optimum for Awassa-83 variety in the same locality, and similar warm sub moist lowland agro-ecologies with similar soil types. Based on these findings, we confirmed that the response of sweet potato varieties is different to applied fertilizers. Hence it could be suggested that there is a need to explore further on sweet potato micro and macro nutrient studies under irrigated conditions, relay and ratoon cropping systems and in different agro-ecologies of the country including variation in dry matter content and consumer preference due to applied fertilizer treatments.

5. References

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