Effect of Tillage Systems and Vine Orientation on Yield of Sweet Potato (Ipomoea batatas L.)

ARTICLE *in* AMERICAN JOURNAL OF PLANT SCIENCES · OCTOBER 2014

DOI: 10.4236/ajps.2014.521332

Ignatius Chagonda

Midlands State University

American Journal of Plant Sciences, 2014, 5, 3159-3165
Published Online October 2014 in SciRes. http://www.scirp.org/journal/ajps
http://dx.doi.org/10.4236/ajps.2014.521332

Scientific Research

Effect of Tillage Systems and Vine Orientation on Yield of Sweet Potato (*Ipomoea batatas* L.)

I. Chagonda*, R. F. Mapfeka, T. Chitata

Department of Agronomy, Faculty of Natural Resources Management and Agriculture, Midlands State University, Gweru, Zimbabwe
Email: *chagondai@msu.ac.zw

Received 8 August 2014; revised 18 September 2014; accepted 9 October 2014

Abstract

In Zimbabwe sweet potato (*Ipomoea batatas* L.) production is practiced under different tillage systems with varying vine orientations, which contribute to variable yields. Limited research on yield loss due to these different practices is available despite that the majority of farmers are growing sweet potatoes to sustain their livelihoods. A field study was carried out at Midlands State University in the 2013/14 rainy season, to determine the effect of tillage systems and vine orientation on yield of sweet potato. A 2 × 3 factorial treatment structure in a randomized complete block design (RCBD), with three replications was used. Tillage systems had two factors (ridge and mound) and three vine orientations were used (horizontal, fold and loop). Data on storage root length, storage root diameter and storage root weight was subjected to Analysis of Variance (ANOVA) at 5% significance level. There was no interaction ($p < 0.05$) between tillage systems and vine orientations on storage root diameter, storage root length and storage root yield. The horizontal vine orientation gave statistically significant ($p < 0.05$) storage roots diameter of width 405 mm. Conversely the loop vine orientation had statistically the least (316 mm) storage root diameter. Horizontal vine orientation had significantly ($p < 0.05$) wider storage roots than the loop vine orientation. The ridge recorded longer (134.2 mm) mean storage root length, while those from mounds had shorter (115.9 mm) root length. The loop and the horizontal vine orientations recorded statistically the highest (35.5 t/ha and 34.8 t/ha respectively) sweet potato storage root yield. On the other hand, the fold vine orientation obtained significantly the lowest (28.7 t/ha) storage root yield. The research concluded that the horizontal and fold vine orientations had the widest storage root diameter and the ridge had longer storage root lengths. The loop and horizontal vine orientations are recommended in sweet potato production if high yields are to be achieved.

*Corresponding author.

How to cite this paper: Chagonda, I., Mapfeka, R.F. and Chitata, T. (2014) Effect of Tillage Systems and Vine Orientation on Yield of Sweet Potato (*Ipomoea batatas* L.). *American Journal of Plant Sciences*, **5**, 3159-3165.
http://dx.doi.org/10.4236/ajps.2014.521332

Keywords

Tillage System, Vine Orientation, Sweet Potato, Mound, Ridge

1. Introduction

Sweet potato (*Ipomea batatas* L.) is a eudicotyledonous warm season crop, which belongs to the Convolvulaceae family [1]. It is a herbaceous plant with creeping perennial vines and adventitious roots [2]. The majority of the sweet potatoes grown in Zimbabwe are for human consumption, as a substitute for bread. Over the years, sweet potato consumption has been on the increase, with an estimated 1 - 7 kg per capita, giving it an economic importance on both rural and urban markets [3]. The relatively high per capita consumption has led to a growing number of farmers producing for commercial purposes. The crop's ability to adapt to marginal environments has made it popular with resource-poor farmers as yields of 15 and 50 tonnes per hectare has been obtained with minimum use of fertilizers and with proper fertilization and sufficient moisture respectively [4]. When compared with other root and tuber crops, sweet potato yields considerably high amount of energy per unit area such that it comes third to the potato (*Solanum tuberosum*) and cassava (*Manihot esculenta*) in production across the world [5]. With the fore mentioned characteristics rainfed sweet potato production has increased over the years, with major production areas stretching from Agro-Ecological Regions I, II and III of Zimbabwe [6].

Smallholder farmers in these regions of Zimbabwe produce sweet potato, using their own experience passed on from early generations. Depending on the experiences and location, farmers use various tillage methods and varying vine orientations for planting since they believe these to produce variable yields [4]. The tillage systems, which include ridges and mounds, optimize infiltration and facilitate root expansion, vary in respective areas depending on environmental conditions and availability of draft animals [7]. Vine placement at planting differs from horizontal, looped and folded vine orientations.

These methods make sweet potato a crop with varying yields across the country, creating a void as to the best tillage as well as vine orientation method to use. In view of this, there is need to establish the best method of planting and sweet potato vine orientation, to enhance reliable yields among farmers. The study, therefore, sought to evaluate the effect of different tillage systems and vine orientation method on yield and yield parameters of sweet potato.

2. Materials and Methods

2.1. Description of Study Site

The experiment was carried out at Midlands State University which is located 10 km southeast of Gweru Central Business District. The grid for the site is 19˚45'S and 29˚84'E and it is in Natural Region III (NR III) of Zimbabwe. The region receives an average annual rainfall of 674 mm which extends from November to February. The Natural Regions in Zimbabwe are a classification of the agricultural potential, from NR I, which represents the highest altitude and wettest area receiving more than 1000 mm of rainfall per year, to NR V that receives the lowest rainfall amounting to less than 450 mm per year and is dry. The average temperature for the site is 18˚C and is elevated 1428 m above sea level. The site has characteristic sandy loams belonging to the fersialitic group with kaolinite clay minerals dominant in the soil [8]. The soil pH for the site is 6.5.

2.2. Experimental Design and Treatments

The experiment was carried out in a 2 × 3 factorial treatment structure arrangement, in a randomized complete block design (RCBD), with three replications. The experiment had two factors: tillage systems (ridge and mound) with three vine orientations: (horizontal, loop and fold) (**Table 1**). Slope was the blocking factor.

2.3. Research Procedure

The cultivar Shanga was selected for the experiment due to its growing popularity with smallholder farmers in Zimbabwe as well as its neighboring countries. It is a white skinned and white fleshed cultivar that is high

Table 1. Table of treatments.

Treatment number	Treatment description
1	Ridge with folded vine
2	Ridge with looped vine
3	Ridge with horizontal vine
4	Mound with folded vine
5	Mound with looped vine
6	Mound with horizontal vine

yielding and has a maturation period of 120 - 150 days.

The trial plot was disc ploughed to a depth of 45 cm in order to incorporate plant residues into the soil as well as improve water infiltration and root penetration into the soil. Nine ridges measuring 120 cm long, 50 cm wide and 40 cm high each and 18 mounds, measuring 55 cm long, 55 cm wide and 40 cm high each, were made. Mounds within each plot were spaced 20 cm between them. Blocks were spaced 100 cm apart with 50 cm spacing between plots.

Vine cuttings measuring 40 cm long with at least six nodes per vine were planted. On planting three to four nodes were buried into the soil for all the treatments. Horizontally planted vines (slide (c)) were done by creating a shallow furrow where the vine cuttings were horizontally placed and two thirds of the vine cutting was covered by soil. For the fold vine orientation (slide (b)), vine cuttings were folded half-way and the folded end was inserted into the soil leaving about a third of the cut ends protruding either sides. For the looped treatments (slide (a)), the vine cuttings were tied to form a loop that was placed in the soil with the tied ends left protruding on the surface. Two vine cuttings were planted at the top of each mound and were spaced 30 cm apart. On each ridge, four vine cuttings were planted at the crest of the ridge in a single row, with a plant spacing of 30 cm, leaving 15 cm spaces at both ends of the ridge.

(a)

(b) (c)

Slides showing vine orientations at harvest time (a) loop (b) folded and (c) horizontal.

The trial plots were planted after the first effective rains, and were rain fed throughout the growing season. Fertilizer application was done by double banding 15 cm away from the crop. A basal fertilizer of compound D fertilizer (7_N:14_P:7_K) was applied 15 days after planting to meet the 75 kg per hectare potassium requirement of the crop.

2.4. Data Collection and Analysis

Data on, growth parameters such as vine lengths were measured at 4, 7 and 10 weeks after planting using a tape measure. Yield parameters, namely: storage root length, storage root diameter and storage root weight were measured at harvesting 19 weeks after planting. Storage root lengths were measured using a meter ruler, the storage root diameter using a Vernier caliper and for storage root weight a digital scale was used.

The data on storage root length, diameter and weight was statistically analysed using Analysis of Variance (ANOVA) technique with GenStat 14 version software. Treatment means were compared by the Least Significance Difference (LSD), at 5% significance level.

3 Results

3.1. Effect of Tillage System and Vine Orientation on Mean Storage Root Diameter

There was no interaction ($p > 0.05$) between the tillage systems and the vine orientations on storage roots diameter. There was no significant difference ($p > 0.05$) between different tillage systems on storage root diameter. However, there was significant difference ($p < 0.05$) between different vine orientations on storage root diameter (**Table 2**). The horizontal vine orientation recorded significantly ($p < 0.05$) the widest (405 mm) storage roots diameter. Conversely the loop vine orientation had statistically the least (316 mm) storage root diameter.

3.2. Effect of Tillage System and Vine Orientation on Mean Storage Root Length

There was no interaction ($p < 0.05$) between the tillage systems and the vine orientations on storage root length. There was no significant difference ($p < 0.05$) between different vine orientations on storage root length. The ridge and the mound had statistically ($p < 0.05$) different root length. The ridge recorded longer (134.2 mm) mean storage root length, while those from mounds had shorter (115.9 mm) root length (**Table 3**).

Table 2. Effect of vine orientation on mean storage root diameter.

Vine orientation	Storage root diameter (mm)
Horizontal	405^{a}
Fold	360^{ab}
Loop	316^{b}
CV (%)	14.5
LSD	67.2
p-Value	$p < 0.05$

*Numbers with different letters (a, b) are significantly different.

Table 3. Effect of tillage system on mean storage root length.

Tillage system	Storage root length (mm)
Ridge	134.2^{a}
Mound	115.9^{b}
CV (%)	11.2
LSD	14.75
p-Value	$p < 0.05$

*Numbers with different letters (a, b) are significantly different.

3.3. Effect of Tillage System and Vine Orientation on Sweet Potato Yield

There was no interaction ($p < 0.05$) between the tillage systems and the vine orientations. There was no significant difference ($p < 0.05$) between the different tillage systems on sweet potato yield. The loop and the horizontal vine orientations recorded statistically the highest (35.5 t/ha and 34.8 t/ha respectively) sweet potato yield. On the other hand, the fold vine orientation obtained significantly the lowest (28.7 t/ha) storage root yield (**Table 4**).

4. Discussion

4.1. Effect of Tillage Systems and Vine Orientation on Mean Storage Root Diameter

The wider storage root diameter recorded in the horizontal vine orientation than loop vine orientation could be attributed to the differences in spatial arrangement of the vine cuttings at planting. In horizontal vine orientation, the subterranean nodes were spaced further apart than those in the loop vine orientation. Formation of a loop design, automatically place subterranean nodes closer to each other. This increase competition as the nodes give rise to storage roots and therefore could have affected the water and nutrient uptake of the subterranean nodes in the loop than in the horizontal vine orientation. The subterranean nodes in horizontal vine orientation had more space to draw up nutrients and water which facilitated photosynthesis and production of photo-assimilates that were deposited in the vascular and anomalous cambia, which are responsible for storage root expansion as noted by Lewthwaite and Triggs (2009) [9].

The structure of the loop vine orientation which resulted in subterranean nodes coming into close proximity of each other could have had detrimental effects on storage root expansion. Initiating storage roots experienced downward development, regardless of their position on the looped vine, due to positive geotropism. This could have contributed to increased competition for space and possibly affected storage root expansion. The horizontal vine orientation had subterranean nodes arranged linearly and had ample space for storage root development, resulting in significantly wider storage roots than those of loop vine orientation. This was consistent with the work of Parwada *et al.* (2011) [4] who also experienced thicker storage roots in horizontal vine orientation over vertical vine orientation.

4.2. Effect of Tillage Systems and Vine Orientation on Mean Storage Root Length

The reason as to why the ridge tillage system recorded higher mean root length as compared to the mound tillage system could be explained in three ways. Firstly, given the same area, ridges utilize gaps that are left between mounds such that ridges gets more soil than mounds, resulting in more space for lengthening of storage roots during development. This would facilitate lengthening of storage roots on ridges over mounds, which had limited space for lengthening before reaching the soil surface.

Secondly, soil moisture and temperature influence the sub-aerial soil microclimate around the sweet potato plant, which has an effect on storage root initiation, growth and development. Because of the protracted structure of ridges, they tend to have lower soil surface temperatures than mounds since they experience elongated heat transfer when compared to conical mounds, which experience circular heat movement [10]. This is enhanced by tillage which results in soil inversion giving rise to increased pore spaces between soil particles, which facilitated penetration of heat through the soil resulting in soil within the first 10 cm below the soil surface

Table 4. Effect of vine orientation on mean storage root yield.

Vine orientation	Storage root yield (t/ha)
Loop	35.5[a]
Horizontal	34.8[a]
Fold	28.7[b]
CV (%)	12.9
LSD	5.47
p-Value	$p < 0.05$

[*]Numbers with different letters (a, b) are significantly different.

having an elevated soil temperature than the next 10 cm [11]. Lastly as Ennin *et al*. (2009) [12] also highlighted, mounds loose more moisture through evaporation than ridges due to the heightened soil surface temperatures, resulting in more soil moisture retention in ridges than in mounds under similar environmental conditions. This could have been the reason why greater root length was found on ridges than on mounds. In ridges, retained soil moisture facilitated nutrient uptake that was used in the process of photosynthesis in formation of assimilates which were partitioned as carbohydrate deposits during storage roots initiation.

4.3. Effect of Tillage System and Vine Orientation on Sweet Potato Yield

The higher yield of the horizontal than fold vine orientation could be because of formation of storage roots at the cut end of horizontal vine cuttings. Although all the vine cuttings had a uniform four subterranean nodes, the horizontal vine orientation had advantage over the fold vine orientation due to the development of adventitious roots at the callus tissue at the cut vine ends. These adventitious roots had a potential of undergoing storage roots initiation, secondary growth and lignification of stele; and develop into storage roots as observed by Rukundo *et al.* (2013) [13]. This may have resulted in horizontal vine orientation being more yielding than fold vine orientation. This is also consistent with the findings by Pandey (2007) [14] who observed the horizontal vine orientation to be more yielding than the fold vine orientation.

Differences in storage root yield due to different tillage systems and vine orientation could also be attributed to different stages of storage roots development at harvesting. Storage root initiation is not spontaneous and can take place over days due to the variability in cutting establishment, which in turn contributes to yield variability [15]. Induction of fibrous roots into formation of storage root varies from plant to plant such that some plants yield with a high number of 4 to 6 storage roots per plant and sometimes less. In related research, Ravi and Indira (1999) [16] also highlighted how some sweet potato cultivars initiate storage roots from 7 - 91 days after planting, which contradicts findings by Belehu (2003) [17] who suggested storage roots initiation takes place between 35 - 60 days after planting.

Without considering the vine orientation, Villordon *et al*. (2009) [15] highlights how yield can vary by up to 50% due to inability to predict the potential number of storage roots that an individual plant of the same cultivar under similar field conditions may produce. In related findings, Firon, *et al.* (2009) [18] also noted that production of storage roots was inconsistent from plant to plant. There is however limited research on the plant intrinsic factors that determine the number of adventitious roots that may develop into storage roots [2]. Different plants, regardless of the tillage system, produced adventitious roots that subsequently developed into storage roots.

5. Conclusion and Recommendations

The study demonstrates that, the horizontal and fold vine orientations produced the widest storage root diameters as compared to the loop vine orientation. The ridge tillage system had the longest storage root lengths when compared to mound tillage system. The loop and horizontal vine orientations were more yielding than the fold vine orientation.

Based on the results, farmers are recommended to use the horizontal and loop vine orientations in sweet potato production since they both are more yielding. Further research should be carried out to consider the plant part to use: growing tip, middle or base of the vine. This results in variation of subterranean buds in age as well as spacing due to their position on the vine.

References

[1] Clarke, A.C. (2009) Origins and Dispersal of the Sweet Potato and Bottle Gourd in Oceania: Implications and Prehistoric Human Mobility. Thesis, Massey University, New Zealand.

[2] Belehu, T. and Hammes, P.S. (2004) Effect of Temperature, Soil Moisture Content and Type of Cutting on Establishment of Sweet Potato Cuttings. *South African Journal of Plant and Soil*, **21**, 85-89. http://dx.doi.org/10.1080/02571862.2004.10635028

[3] Mutandwa, E. and Gadzirai, C.T. (2007) Comparative Assessment of Indigenous Methods of Sweet Potato Preservation among Smallholder Farmers: Case of Grass, Ash and Soil-Based Approaches in Zimbabwe. *African Studies Quarterly*, **9**, 85-98.

[4] Parwada, C., Gadzirai, C.T. and Sithole, A.B. (2011) Effect of Ridge Height and Planting Orientation on *Ipomoea batatas* (sweet potato) Production. *Journal of Agricultural Biotechnology and Sustainable Development*, **3**, 72-76.

http://www.academicjournals.org/JABSD

[5] Nedunchezhiyan, M., Byju, G. and Jata, S.K. (2012) Sweet Potato Agronomy, Fruit, Vegetable and Cereal Science and Biotechnology. Global Science Books, 1-10.

[6] Mutandwa, E. (2008) Performance of Tissue-Cultured Sweet Potatoes among Smallholder Farmers in Zimbabwe. *The Journal of Agrobiotechnology Management and Economics*, **11**, 48-57.

[7] Andrade, M., Barker, I., Cole, D., Dapaah, H., Elliot, H., Fuentes, S., Gruneberg, W., Kapinga, R., Kroschel, J., Labarta, R., Lemaga, B., Loechl, C., Low, J., Mwanga, R., Ortiz, O., Oswald, A. and Thiele, G. (2009) Unleashing the Potential of Sweet Potato in Sub-Saharan Africa: Current Challenges and Way forward. International Potato Centre (CIP), Lima, 197.

[8] Nyamapfene, K. (1991) Soils of Zimbabwe. Nehanda Publishers, Harare, 179.

[9] Lewthwaite, S.L. and Triggs, C.M. (2009) Preliminary Study of the Spatial Distribution of Sweet Potato Storage Roots. *Agronomy New Zealand Issue*, **39**, 111-122.

[10] Agbede, T.M. and Adekiya, A.O. (2011) Evaluation of Sweet Potato (*Ipomoea batatas* L.) Performance and Soil Properties under Tillage Methods and Poultry Manure Levels. *Emirates Journal of Food and Agriculture*, **23**, 164-177. http://www.ejfa.info/index.php/ejfa/article/view/6454/3292

[11] Odjugo, P.A.O. (2008) The Effect of Tillage Systems and Mulching on Soil Microclimate, Growth and Yield of Yellow Yam (*Dioscorea cayenensis*) in Midwestern Nigeria. *African Journal of Biotechnology*, **7**, 4500-4507.

[12] Ennin, S.A., Otoo, E. and Tetteh, F.M. (2009) Ridging, a Mechanized Alternative to Mounding for Yam and Cassava Production. *West African Journal of Applied Ecology*, **15**.

[13] Rukundo, P., Shimelis, H., Laing, M. and Gahakwa, D. (2013) Storage Root Formation, Dry Matter Synthesis, Accumulation and Genetics in Sweet Potato. *Australian Journal of Crop Science*, **7**, 2054-2061.

[14] Pandey, S.K. (2007) Vegetables, Tubers and Spice Crops: Potato and Tuber Crops. Central Potato and Research Institute, Shimla. http://nsdl.niscair.res.in/jspui/bitstream/123456789/409/2/Revised%20Potato%20%26%20Tuber%20Crops.pdf

[15] Villordon, D.R., La Bonte, D.R., Firon, N., Kfir, K., Pressman, E. and Schwartz, A. (2009) Characterization of Adventitious Root Development in Sweet Potato. *HortScience*, **44**, 651-655.

[16] Ravi, V. and Indira, P. (1999) Crop Physiology of Sweet Potato. *Horticultural Reviews*, **23**, 277-316.

[17] Belehu, T. (2003) Agronomical and Physiological Factors Affecting Growth, Development and Yield of Sweet Potato in Ethiopia. Ph.D. Thesis, University of Pretoria, Pretoria.

[18] Firon, N., LaBronte, D., Villordon, A., McGregor, C., Kfir, Y. and Pressman, E. (2009) Botany and Physiology: Storage Root Formation and Development. In: Loebenstein, G. and Thottapilly, G., Eds., *The Sweet Potato*, Springer Science + Bussiness Media BV, 13-26.