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Effect of Earthing up Frequencies and Tuber Seed Form on Yield and Profitability of Potato (*Solanum tuberosom*) Production in Bale highlands

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Abstract

Poor ridging or hilling up and inappropriate tuber seed size for planting are some of the factors affecting yield and market quality in potato production system. Hence, this experiment was conducted at Sinja and Shallo areas of Bale for three consecutive years with the objective of determining the effect of tuber seed form and hilling up frequencies on yield and yield traits of Potato. Two seed forms (half and full seed size) and four level of hilling up, including the control were combined in factorial arrangements and conducted using split plot design where tuber form was considered as main plot and hilling up frequency as sub-plot. The result of the study revealed that the highest total tuber yield was obtained from three times hilling up followed by two times, but both means are statistically insignificant. Three and two times hilling up had significantly increased total tuber yield by 24.7% and 15.5% over the control, respectively. On the other hand, the yield increase of marketable and total tuber yield were 20% and 33%, respectively when full sized seed form was used as compared to half sized one. Interaction effect also indicated that, planting of full sized tuber seed with three times hilling showed the highest marketable and total tuber yield followed by use of full sized with two times earthing up practices, but statistically both are at par. From economic point of view, the use of full sized seed with three times hilling up resulted in the highest net benefit and marginal rate of return followed by the two times hilling up frequencies. Thus, farmers can get more income when they practice three times hilling up in combination with the use of full sized tuber seed though they invest more extra cost as compared to two times hilling up. However, full sized seed planting with two times hilling up of potato could also be profitable in areas where the soil is less compacted or more loamy types and/or for some farmers who may not afford extra investment cost for three times hilling up frequency.

Key words: Potato, Tuber seed form, hilling/earthing up frequency

Introduction

Potato (*Solanum tubersum*) is among the principal tuber crops grown in Ethiopia. It is a very important food and cash crops in Ethiopia, especially in the high and mid-altitude areas. Potato, togetether with wheat and rice, is considered as one of the most important staples in the human diet (Dennis and Decoteau, 2000). It serves as food and cash crop for small scale farmers, occupies the largest area compared to other vegetable crops and produces more food per unit area when compared to cereal crops. Thus it plays a great role in the process of food self-sufficiency, food security, nutrition, income generation and poverty alleviation and provision of employment in the production, processing and marketing sub-sectors (Charles L. *et al*, 2007 and Douglas H. 1987). Since potato has relatively short growing tropical crop, it is one of acceptable alternative crops in order to support high population pressure in developing countries like Ethiopia and ensure in minimizing hunger (Edward H. and Lema D., 1992).

Most soil types generally considered as suitable for potato production. The soils for production of the crop should be fine, loose and none compact layers that do not hinder root penetration. Potatoe is propagated vegetatively from tubers either whole or cut into pieces. Yield of the crop can be regulated by changing the seed rate: by means of the planting density or by the size of the seed tubers (CIP 2010). Ridging which is a normal practice in potato production refers to the practice of earthing (hilling) up around the plant. Proper ridging increases tuber yield by creating favourable condition for tuber initiation and development. It helps to prevent greening of tubers. Ridging operations may also provide a form of weed control mechanism. Studies show that ridging of potato at least twice during the growing period increases tuber yield by 10-20% compared to non-ridging practice. Poor ridging around potato plant could expose the tuber to sunlight, high temperature, diseases and insect damage. Studies showed that a yield loss as high as 8% is attributed to poor ridging (Gebremedhin. *etal*, 2008). Moreover, inappropriate seed size and form could also result in yield reduction.

When large tubers tubers are planted, the growth is faster because the large tubers have greater food reserve available for each sprout than small tubers. Biger seed tubers may result in the production of too many stems which eventually produce too many tubers that may compete for growth factors in soil. On the other hand, if seed tubers are smaller, they will have small number of stems that produce only a few tubers thereby reducing yield (Zebenay Dagne, 2015). Cut tubers may be deteriorated by bacteria and have less food reserve for the emerged seedlings which results in poor growth leading to low yield. On the other hand, full tubers have more reserved materials and not affected by bacterial activity resultin in higher yield as compared to cut tubers (Imran Hossain, 2014). Hence, it is apparently important to identify and recommend the most appropriate and optimum earthing (hilling) up frequency as well as themost suitable tuber form to boost productivity of potato in the potato producing areas of Bale.

Materials and Methods

Description of study area: The experiment was conducted at Jafera and Shallo during 'Gena' cropping season for three years from 2011-2013. Jafera is located in Bale zone at $7^0 7'$ N and $40^0 10'$ E, at 2440 meters above sea level (m.a.sl) and 464 km southeast of Addis Ababa. It receives an average rainfall of 489.87mm during the Gena (cropping) season. The minimum and maximum temperatures are 9.05 and 21.02 ^{0}C, respectively. The dominant soil type is pellic vertisol which is slightly acidic.

Shallo is located in Bale zone at $7^0 8'$N and $40^0 11'$ E, at 2396 meter above sea level (m.a.sl) and 443 km southeast of Addis Ababa. Its climatic condition is categorized under cool, sub-humid agro-climatic zone of Bale highlands. It receives an average rain fall of 425.78 mm during the Gena season. The minimum and maximum temperatures are 7.95 and 21.6 ^{0}C, respectively

Experimental Procedures: The experimental field was cultivated to a depth of 25-30 cm by a tractor and ridges were made manually after leveling. Area of experimental plot was 6 m^2 (3m × 2m). Recommended N and P fertilizers in the form of DAP (195 kg/ha) and UREA (165/kg) were applied. DAP was applied at time of planting while half of N source was applied at time of planting and the remaining half was applied at the time of first earthing up (two weeks after emergency).

Experimental materials, treatments combinations and design

Full and half tuber seeds of 'Ararsa' variety, which was released by Sinana Agricultural Research Center, were planted as per treatment arrangements after the rain commenced and the soil was moist enough to support germination and emergency. Two types of tuber forms (full and half tuber seed) and four levels of earthing (hilling) up frequency including control i.e no ridging (control), one time ridging (at two weeks after emergence), two times ridging (at two and four weeks after emergence),

and three times ridging (at two, four and six weeks after emergence) frequencies were combined in factorial arrangements using split plot design with three replications. The tuber form was used as main plot while earthing (hilling) up frequency as a sub plot. Tuber seed was planted in four rows having 3m length with a distance of 0.75 m and 0.3 m between rows and plants, respectively. Before planting, the cut seeds were stored in warm humid place for 2-3 days to allow fresh cut surface to heal which help the seed in preventing from rotting when planted.

Agronomic data and analysis: some of collected agronomic data which were considered in this study were date to emergeny,date of flowering, plant height, date to maturity, number of hills per plot, number of stems per hill, marketable and unmarketable tuber yield and total tuber yield. Finally, the analyses of variance were carried out using GenStat 15th edition computer software. Least Significant Difference (LSD) method was used to separate differences among treatment means. The partial budget analysis for hilling up frequency and tuber form was done according to CIMMYT, 1988.

Results and Discussion

Analysis of variance

The analysis of variance indicated significant difference ($p \leq .05$ or 0.01) among means of plant height, date of emergency, date of maturity, marketable and unmarketable yield and total yield for different hilling up frequences. On the other hand, there was no significant different for hill per plot, number stem per hill, and date of flowering for different hilling up frequencies. Plant height, date of emergency, date of flowering and date of maturity were not significantly ($p \leq 0.05$ or 0.01) different for full and half tuber forms (Table 1).

Combined effect of hilling up frequency and tuber seed form

The study revealed that plant height, date of maturity, marketable and unmarketable tuber yield and total tuber yield were influenced by different hilling up frequencies. However it was none significant for number of hill per plot, number stem per hill, and date of flowering. Maximum plant height was recorded when one time hilling up and followed by non-ridging were practiced while the lowest height (33.9cm) was recorded when three times hilling up was applied. This is because, when more hilling is practiced the root system growth may have a temporary priority over top growth enabling extractable water and nutrients to increase tuber size and reduces plant height. The highest total tuber yield was obtained from three times hilling up frequency followed by two times, but both means are statistically at par as compared to local practice. However, one time hilling up frequency did not significantly enhance total tuber yield compared to three times hilling up and even similar yield was obtained compared with the non-ridging practice (control). Three and two times hilling up frequencies had significantly increased total tuber yield by 24.7% and 15.5% over the control, respectively. This result is similar with previous reports by (Gebremedhin *et al.*, 2008) who indicated that ridging at least twice during the growing period of the crop could increase tuber yield by 10-20% compared to the non-ridging cntrol. In addition, the formation of ridges may improve conditions for tuber development which may result in a positive effect on tuber yield. Hilling increases yields by increasing the tuber number per plant, preventing the tubers from greening (Darwin H.Pangaribuan, 1991).

Similar to total tuber yield, the highest marketable yield was obtained under three times(13.13t/ha) and followed by two times(11.91t/ha) hilling up even if both means are statistically at par and yield increasment over the control were 27.5% and 16%, respectively. Moreover, marketable yield attained under one and two times hilling up and no-ridging were statistically similar. Eventhough marketable and total tuber yield under one time hilling up were significant over the control, significantly higher unmarketable yield was recorded in control plot (non-ridging) than one time hilling up.

The main effect of seed form significantly affected days to emergency, number of hill per plot, number of stem per plot, marketable and unmarketable yield and total yield while days to flowering and maturity as well as plant height were not significantly different.

The result clearly reveled that both hill and stem number per plant were significantly higher when full sized seed form was used for planting than half sized ones. Similarly, significantly higher marketable, unmarketable and total tuber yield were obtained when full sized seed form was used as compared to half sized one (Table 2). The yield increasment of marketable and total tuber yield due to use of full sized seed form were 20% and 33%, respectively as compared to half sized one. Similar results reported by Iran Hossain (2014) revealed that the use of whole tuber for planting gives more yield than half cut seed tuber. This is because, the whole seed tuber had more number of eyes and more food content that produce more number of healthy stem per hill. This contributed to the production of increased number of stolons which ultimately increased yield.

The interaction effect of hilling up frequency and tuber form had no effect on the plant height, date of flowering and date of maturity while number of hill per plot, number of stems per hill, marketable and un marketable yield and total yield were influenced by the interaction of hilling up frequency and tuber forms.

Planting of full sized tuber seed with three times hilling resulted in the highest marketable and total tuber yield followed by the use of full sized seed from with two times earthing up practices which are statistically at par. In addition, uses of whole sized seed for planting in combination with triple hilling up significantly increased total tuber yield by 26% and 50% when compared with full and half sized seed planting under non-ridging practice, respectively. Similar results were observed for both marketable and unmarketable tuber yield when full sized seed with two times hilling up were practiced as compared to use of either half or full sized seed was planted in non ridging practice. In addition to tuber yield, planting of full sized tuber seeds with double or triple hilling up significantly increased the number of hills per plant and stems per plant while half sized seed under non-ridging practice resulted in the lowest value.

Partial budget analysis

Economic analysis of hilling up frequency and tuber seed form for potato production was conducted. Total costs that varied as well as gross field benefits and net benefits of the treatments are shown in table 4. The results showed that uses of full sized seed with two times hilling up frequencies resulted in the highest net benefit followed by full sized with three times hilling up frequencies. However, dominance analysis showed that two and three times hilling up with half tuber form as well as one time hilling up with half and full tuber form resulted in a lower net benefit compared to the net benefit of the next low cost treatment and hence not considered for marginal analysis.

Analysis of the marginal rate of return (MRR) indicated that two times hilling up frequency with full tuber has resulted in the highest net benefit and marginal rate of return followed by three times hilling up frequency with full tuber form (Table 5). Therefore, farmers can get more revenue from three times hilling up in combination with uses of full sized tuber seed though they invest more extra cost

as compared to two times hilling up and the use of full sized seeds. However, full sized seed planting with two times hilling up of potato could also be profitable in areas where the soil is less compacted or more loamy types and for some farmers who may not afford extra investment for three times hilling up frequency.

The marginal rate of return analysis revealed that using full seed sized of potato and two times hilling up frequency can provide with about 961 ETH birr, while using full seed sized of potato and three times hilling up frequency can provide with about 1374 ETH birr.

Conclusion and Recommendation

The investigation revealed that the highest total tuber yield was obtained from three times hilling up frequency followed by two times but both means are statistically at par. Three and two times hilling up frequences had significantly increased total tuber yield by 24.7% and 15.5% over the control, respectively. On the other hand, the yield mcreasment of marketable and total tuber yield were 20% and 33%, respectively when full sized seed form was used as compared to half sized one. Interaction effect also indicated that planting of full sized tuber seed with three times hilling showed the highest marketable and total tuber yield followed by use of full sized with two times earthing up practices, but both are at par. From these results, we can conclude that when we increase hilling up frequency from 0 to 3 the root of potato can get more soil and bear more tubers. Further, the use of full sized seed for planting can reduce the probability of tuber to deteriorate and the tubers can feed the newly growing seedling for some period of time than half sized tuber seeds.

The result of economic analysis revealed that the use of full sized seed with three times hilling up frequencies resulted in the highest net benefit and marginal rate of return followed by two times hilling up frequency with full tuber form (Table 5). Thus, farmers can get more income when they practice three times hilling up in combination with the use of full sized tuber seed though they invest more as compared to two times hilling up. However, full sized seed planting with two times hilling up of potato could also be profitable in areas where the soil is less compacted or more loamy types, in which stolons of potato can easily penetrate, and for some farmers who may not afford extra investment for three times hilling up frequency.

Table 1: ANOVA table of earthing up frequency, tuber form and interaction

Source of variation	Df	P value(0.05)								
		PH	NSPH	NHPP	DE	DF	DMM	MYLD	UNMYLD	TOTYLD
Replication(R)	2									
Tuber form(T)	1	0.64	0.037	0.042	0.74	0.488	0.02	0.02	0.001	0.004
Error	2									
Location(L)	1	0.23	0.07	0.03	0.54	0.06	0.04	0.71	0.02	0.62
Year(Y)	2	0.19	0.40	0.91	0.46	0.08	0.03	0.036	0.52	0.031
Earth up fr (E)	3	0.04	0.67	0.72	0.09	0.77	0.049	0.044	0.039	0.02
T*E	3	0.86	0.024	0.04	0.67	0.79	0.58	0.035	0.001	0.049
Error	2									
Total	143									

NHPP=number of hill per plot PH=plant height NSPH= number of stem per hill DE= date of emergency DF=date of flowering DM= date of maturity MYLD= marketable yield=UNMYLD= unmarketable yield TOTYLD=total tuber yield.

Table 2: Combined effect of hilling up frequency on yield and yield parameters of potato

Hilling up frequency	PH	DM	MYLD(Qt/ha)	UNMYLD (Qt/ha)	Total Yield (Qt/ha)
Three times	33.9^{b}	106.5^{a}	131.30^{a}	18.98^{ab}	150.28^{a}
Two times	35.0^{b}	103.67^{ab}	119.54^{ab}	19.62^{a}	139.16^{ab}
One time	41.7^{a}	104.5^{ab}	109.81^{b}	13.74^{c}	123.55^{bc}
control	36.7^{ab}	99.5^{b}	102.99^{b}	17.51^{ab}	120.5^{c}
LSD	6.31	4.6	20.39	5.04	18.51
CV (%)	13.6	5.96	16.7	23.3	12.9
SL	*	*	*	**	*

CV- Coefficient of Variation. SL= significance level, ns= non significant, * significant at P≤0.05 ** significant at P≤0.01 PH=plant height DM= date of maturity MYLD= marketable yield=UNMYLD= unmarketable yield Qt/ha= quintals per hectare

Table 3: Combined Means as affected by tuber seed form on yield and yield parameters of potato

Tuber form	NHPP	NSPH	MYLD (Qt/ha)	UNMYLD (Qt/ha)	Total Yield (Qt/ha)
Full	14.5^{a}	53.6^{a}	126.4^{a}	24.63^{a}	151.03^{a}
Half	10.58^{b}	32.2^{b}	105.5^{b}	10.29^{b}	115.79^{b}
LSD	1.75	6.96	14.19	3.36	12.6
CV (%)	7.8	16	40.37	3.6	9.4
SL	*	*	*	**	*

CV= Coefficient of Variation, SL= significance level ns= non significant, * significant at P≤0.05, ** =significant at P≤0.01, NHPP=number of hill per plot, NSPH= number of stem per hill MYLD= marketable yield=UNMYLD= unmarketable yield Qt/ha= quintals per hectare

Table 4: Interaction effect of hilling up and tuber forms on yield and yield parameters of potato

HILFRE	TUBFORM	NHPP	NSPH	MYLD (Qt/ha)	UNMYLD(Qt/ha)	TOTYLD (Qt/ha)
Three times	Full	14.67^{a}	54.7^{a}	146.57^{a}	26.59^{a}	173.2^{a}
Two times	Full	14.00^{a}	57.3^{a}	134.3^{a}	24^{a}	158.3^{ab}
Three times	Half	11.33^{a}	35.0^{b}	116.03^{b}	11.37^{b}	127.4^{c}
One time	Full	15.00^{a}	56.7^{a}	114.21^{b}	21.36^{a}	135.6^{bc}
None	Full	14.33^{a}	45.7^{a}	110.32^{b}	26.58^{a}	136.9^{bc}
One time	Half	8.67^{b}	31.0^{b}	105.41^{b}	6.12^{c}	111.5^{c}
Two times	Half	10.67^{b}	30.0^{b}	104.77^{b}	15.25^{b}	120.0^{bc}
None	Half	11.67^{b}	33.0^{b}	95.66^{b}	8.43^{c}	104.1^{cd}
LSD		3.57	18.93	17.66	4.36	16.03
CV (%)		16.3	19.1	15.3	2.5	11.6
SL		*	*	ns	**	*

CV= Coefficient of Variation, SL= significance level, ns= non significant, * =significant at P≤0.05, ** =significant at P≤0.01, NHPP=number of hill per plot, NSPH= number of stem per hill MYLD= marketable yield=UNMYLD= unmarketable yield TOTYLD=total tuber yield Qt/ha= quintals per hectare

Table 5: partial budget for hilling up frequency and tuber seed form on potato

HF	TF	TOTYLD (QT/ha)	GFB	HU CO	TF CO	TVC	NBC	Dominance Analysis
None	half	104	26023	0	136	136	25886	-
None	full	137	34225	0	272	272	33953	
One time	half	111	27750	252	136	388	27362	D
One time	full	136	33893	252	272	524	33368	D
Two times	half	120	30005	504	136	640	29365	D
Two times	full	158	39575	504	272	776	38799	
Three times	half	127	31850	756	136	892	30958	D
Three times	full	173	43290	756	272	1028	42262	

HU= hilling up frequency, TF=tuber form, TOTYLD=total tuber yield Qt/ha= quintals per hectare GFB=Gross field benefit (ETB), HUCO=hilling up cost (ETB), TFCO=tuber form cost (ETB), TVC=total variable cost (ETB), NBC=net benefit (ETB).

Table 6: Marginal return (MRR) for hilling up frequency and tuber seed form on potato

HF	TF	TOTYLD (QT/ha)	GFB	HU CO	TF CO	TVC	NBC	MTVC	MNB	MRR%
None	full	137	34225	0	272	272	33953	-	-	-
Two times	full	158	39575	504	272	776	38799	504	4846	961
Three times	full	173	43290	756	272	1028	42262	252	3463	1374

HF= hilling up frequency, TF=tuber form, TOTYLD=total tuber yield, Qt/ha= quintals per hectare GFB=Gross field benefit, HUCO=hilling up cost, TFCO=tuber form cost, TVC=total variable cost, NB=net benefit, MTVC=marginal total variable cost, MNB=marginal net benefit, MRR=marginal ret of return

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