



Research Article

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

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Abstract

Poor ridging or hilling up and inappropriate tuber seed size for planting area are some of the factors affecting yield and marketable quality of potato production. Due to these facts, the experiment was conducted at Sinja and Shallo areas of Bale for three consecutive years with the objective of determining the effects of the tuber seed size 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, tuber form was considered as main plot while 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 frequency followed by two times, but both means are statistically similar. Three and two times hilling up frequency 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 and followed by use of full sized with two times earthing up practices, but both are at par. From economic point of view, uses of full sized seed with three times hilling up frequencies 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 uses of full sized tuber seed though they invest more extra cost as compared to two times hilling up. However, full sized seed planting and 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.

Keywords: Potato; Tuber seed form; Hilling/earthing up frequency

Introduction

Potato (*Solanum tuberosum*) is among the principal tuber crops grown in Ethiopia. It is a very important food and cash crop in Ethiopia, especially in the high- and mid-altitude areas. Potato is ranked with wheat and rice as one of the most important staples in the human diet [1]. It serves as food and cash crop for small scale farmers, which occupies the largest area, compared to other vegetable crops and produces more food per unit area and time as compared to cereal crops like maize. Thus, it plays a great role in the process of food self-sufficiency, food security and nutrition, income generation and poverty alleviation and provision of employment in the production, processing and marketing sub-sectors [2,3]. Since potato has relatively short growing season it is one of the acceptable alternative crops in order to with stand the population pressure in developing countries, like Ethiopia and ensure in minimizing hunger [4].

Most soil types are suitable for potato production. The soils for production of the crop should be fine, loose and none compacted layers that hinder root penetration [5]. Potatoes are propagated vegetative 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 [6]. Ridging refers to, as a normal practice in potato production, the practice of earthing (hilling) up around the plant. Proper ridging increases tuber yield by creating favourable condition for tuber initiation and development [5]. 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 increased 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 sacrificed due to poor ridging [5]. Moreover, inappropriate seed size and form could also result in yield reduction.

When planting large tubers the growth is faster because the large tubers have greater food reserve available for each sprout than small tubers. Big 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 small, they will have small number of stems that produce only a few tubers, thereby reducing yield [7]. Cut tubers may be deteriorated by bacteria and have less food reserve for the emerged seedlings which resulted to poor growth performance that resulted to low yield. On the other hand, full tubers have more reserved materials and not affected by bacterial which resulted to more yield as compared to cut tubers [8]. Hence, it is important to identify and recommend the most appropriate and optimum earthing (hilling) up frequency and tuber size to boost productivity of the crop in the potato producing areas of Bale.

Materials and Methods

Description of the 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°7' N and 40°10' E, at 2440 meters above sea level (m.a.s.l) 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 °C, respectively. The dominant soil type is pellic vertisol and slightly acidic with pH range from 6.2-6.4. Shallo is located in Bale zone at 7°8'N and 40°11' E, at 2396 meter above sea level (m.a.s.l) 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 °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 6m² (3m x 2m). Recommended N and P chemical fertilizer in the form of diammonium phosphates (195 kg/ha) and urea (165/kg) were applied. Diammonium phosphates was applied at time of planting while half of N source was applied at time of planting and the remaining half was 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 had commenced and the soil was moist enough to support emergency. Two types of tuber forms (full and half form of tuber seed) and four levels

of earthing (hilling) up frequency including control; no ridging (control), one time (at two weeks after emergence), two times (at two and four weeks after emergence), and three times (at two, four and six weeks after emergence) earthing up frequencies were combined in factorial arrangements using split plot design with three replicates. 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 a 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 emergency, date of flowering, plant height, date to maturity, number of hill per plot, number of stem per hill, marketable and unmarketable tuber yield and total tuber yield. Finally, the analyses of variance were carried out using Gen Stat 15th edition computer software. Least significant difference (LSD) values were used to separate differences among treatment means at 0.05% probability. The partial budget analysis for hilling up frequency and tuber form was done according to CIMMYT [9].

Results and Discussion

Analysis of variance

The analysis of variance indicate a presence of significant at $p \leq 0.05$ or 0.01 plant height, date of emergency, date of maturity, marketable and unmarketable yield and total yield for different hilling up frequency. On the other hand there is no significant different for hill per plot, number stem per hill, and date of flowering for different hilling up frequency. 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 form

Combined effect of hilling up frequency and tuber seed form

The investigation 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. This is because when more hilling is practiced root system growth may have a temporary priority over top growth causing extractable water and nutrients to increase tuber 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 and even time hilling up. 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 non-ridging practice (control).

Three and two times hilling up frequency had significantly increased the total tuber yield by 24.7% and 15.5% over the control, respectively. This result is similar with previous report by Gebremedhin et al. [5] who indicated that ridging at least twice during the growing period of the crop could be increased tuber yield by 10-20% compared to the control. 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 as reported by Darwin [10] (Table 1).

Table 1: Combined effect of hilling up frequency on yield and yield parameters of potato.

| Hilling up frequency | PH | DM | MYLD (Qt/ha) | UNMYLD (Qt/ha) | TOTYLD (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; TOTYLD: Total Tuber Yield; Qt/ha: Quintals per Hectare

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 increase over the control were 27.5% and 16%, respectively. Moreover, marketable yield performance under one and two times hilling up and no-ridging was statistically similar. Even though marketable and total tuber yield under one time hilling up were significant over the control, significantly higher unmarketable yield was recorded in control plot (none 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, and plant height were not significant.

The result clearly revealed 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 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. Similar result reported by Imran [8] 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. (Table 2) Combined Means as affected by tuber seed form on yield and yield parameters of potato.

Table 2: Combined effect of tuber form on yield and yield parameters of potato

| Tuber form | NHPP | NSPH | MYLD (Qt/ha) | UNMYLD (Qt/ha) | TOTYLD (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; TOTYLD: Total Tuber Yield; Qt/ha: Quintals per Hectare

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 up showed the highest marketable and total tuber yield and followed by use of full sized 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 enhanced number of hill per plant and number of stem per plant while half sized seed under non-ridging practice significantly showed the lowest (Table 3).

Table 3: 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 | 18.9 ³ | 17.66 | 4.36 | 16.03 |
| CV (%) | | 16.3 | 19.1 | 15.3 | 2.5 | 11.6 |
| 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 TOTYLD: Total Tuber Yield; Qt/ha: Quintals per Hectare

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 treatment 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, 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.

Table 4: 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)

Table 5: 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

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 the 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 uses of full sized seeds. However, full sized seed planting and with two times hilling up of potato could also be profitable in area where the soil is less compacted or more loamy types and for some farmers who may not afford extra investment cost 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 yield about 961 Ethiopian Birr, while using full seed sized of potato and three times hilling up frequency can yield about 1374 Ethiopian 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 frequency 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 and followed by use of full sized with two times earthing up practices, but both are at par. From these result, 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, use of full sized seed for planting the probability of tuber to deteriorate is less and the tuber can feed the newly growing seedling for some period than half sized tuber seeds.

The result of economic analysis revealed that uses of full sized seed with three times hilling up frequencies resulted in the highest net benefit and marginal rate of return followed by the 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 extra cost as compared to two times hilling up. However, full sized seed planting and 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 penetrated, and for some farmers who may not afford extra investment cost for three times hilling up frequency.

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