

Full Length Research Paper

Effect of flower bud on tuber yield and quality of potato (*Solanum tuberosum* L.) varieties in Horo District, Western Ethiopia

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The experiment was conducted in Horo District of Western Ethiopia. Five-by-two factorial experiment arranged in a randomized complete block design was the method used. The purpose of the experiment was to compare the varietal differences and to evaluate the effects of flower bud removal on tuber yield and quality in Irish potato varieties. Pruning treatments viz. normal growings were applied to five potato cultivars, Guduru, Horro, Beletech, Menagsha, and Jalene. Randomized complete block design arranged in factorial with three replications employed. The results of analysis of variance revealed a significant difference between varieties. Effects of flower bud also showed significant variations except the number of tubers per hill. Interaction between cultivars and treatments showed significant differences for some quality characters. Variety Beletech interacting with bud removal records the highest (18.13%) and (1.51) in dry matter content and specific gravity, respectively. In contrast, Guduru and Jalene interaction with bud removal record (13.5%) and (1.05) in dry matter and specific gravity, respectively. Removal of flower buds decreased total leaf area, plant height, and increased tuber yield by 23.5%, and average tuber mass by 21.5% compared to the unpruned. The result clearly indicated that removal of buds of the upper two younger leaves improved the tuber yield and quality of potatoes. Most of the characters showed positive correlation to each other unless for total marketable tubers per hill and total un-marketable tubers per hill, average individual tuber weight per hill and total unmarketable tuber number per hill, and average individual tuber weight per hill and total tuber number per hill. This indicates that as the number of tubers per hill increases, the total assimilated storage per tuber decreases. The result is of paramount importance to increase the productivity of potatoes in the study area.

Key words: Flower bud, marketable yield, bud removal, tuber

INTRODUCTION

Root and tuber crops are said to be one of the most efficient crops in converting natural resources, labor, and capital into high quality food with wide consumer

acceptance (Horton, 1980). The food potential of root and tuber crops has not yet been fully exploited and utilized despite their significant contributions towards

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food security, income generation, provision of food energy, and resource based conservation (Gebremedhin et al., 2008). The most grown potatoes are tetraploid ($2n = 4x = 48$), but farmers in the Andes grow diploid ($2n = 2x = 24$), triploid ($2n = 3x = 36$), and pentaploid ($2n = 5x = 60$) cultivars (Watanabe, 2015). In Ethiopia, potato production has increased during the “Meher” season as a result of improved varieties, being tolerant to major potato disease, late blight especially in the areas of major potato growing regions of the country. It is a short cycle crop with three to four months cropping cycle, are well suited to double cropping particularly in rain-fed systems and has significant advantage over grain crops which require relatively longer time to mature. Its short growing cycle allows for flexible planting and harvesting times and also permits quick production of foods to augment “hunger months” of August to October before grain harvests when people lack sufficient food to meet their basic caloric and nutritional requirements (Degebas, 2019).

According to Kolech et al. (2019), potato is considered as a food security crop that helps to meet the rising food demands in the tropical highlands of Sub-Saharan Africa. Due to potato's short cropping cycle and higher production per hectare per day when compared to other arable crops (FAO, 2015); potato provides hope for improving the lives of millions of poor farmers in the risk-prone highlands. Ethiopians main economy is based on agriculture absorbing 85% of employment and contributing 45% of the National Domestic product. This sector relies mainly on biodiversity, which the country is endowed with one of the twelve Vavilovian centers for its genetic diversity and this resource has been contributing as a source of raw material for agriculture, health care needs of human and livestock, industry, cash generating for the country as well as keeping the chronologic balance (Amsalu et al., 2008).

Ethiopia is one of the principal potato producing countries in Africa and probably displays a unique position for having the highest potential area for cultivating potatoes (Degebas, 2019). The area under potato production in Ethiopia in the year 2013/14 was about 66,745 hectares with an average national yield of 117 quintals per hectare for the main cropping season. Out of this, the produce in East Hararghe covered 2,207.12 hectares of land with an average yield of 193 quintals per hectare. Eastern Hararghe (Haramaya and Kombolcha Woredas) is one of the major potato producing areas in the country. In addition to satisfying domestic demand, the potato produce in the region is being exported to regional markets like Djibouti and Somalia, and Middle East countries and the Western European. For instance, out of the total volume of potatoes marketed in Somalia, 75 percent is supplied from East Hararghe and about 25 percent from the central part of Ethiopia (Amsalu et al., 2008).

Potato prefers cool weather and temperatures between 16 and 25°C favor foliage growth, net photosynthesis,

and tuberization. Although potato is a remarkably adaptable crop, its expansion has been restricted by high temperatures in some regions of the world (Levy, 1986). For instance, in Ethiopia, about 35% of the available agricultural land is situated in the semi-arid regions of the country, where potato cultivation is not being practiced due to unfavorably high temperatures throughout the year. High temperatures cause yield and quality reduction and are considered the major constraints for potato production in the tropics (Degebas, 2019).

Many researchers have studied the effect of high temperature on growth, tuber yield, and quality of potatoes (Menzel, 1980; Steward et al., 1981; Reynolds and Ewing, 1989). However, very little work has been done regarding the effect of disbudding on the growth and productivity of potatoes under hot tropical conditions where unfavorably high temperatures limit were its successful production.

As a food crop, potato has a high potential to supply quality food within a relatively short period, which in turn plays an important role in contributing to the household food security, nutritional value; generating income and employment opportunities for poor households. However, the supply is neither sufficient nor constant to satisfy the demand for the market at both market outlets (Tekalign and Hezekeil, 2015). Thus, the production level of the sector requires further expansion to narrow down the gap between the available supply and the demand for domestic and international markets.

Despite of its importance and wider adaptability, its production and productivity are threatened by several factors. Among the factors, disease and pest lock of improved seed management and soil factors are known. In plant physiology, flowers, fruit, older leaves, seed, and other mature plant parts are sinker organs and known for using more assimilates compared to the other plant parts. In potatoes and some plant, flowers and seeds are not necessary unless for breeding purposes.

Vegetative buds and younger leaves are important sites of gibberellin synthesis (Cai et al., 2016), and their removal can substantially modify the phyto-hormone levels in the plant. This was observed in potatoes in which tuberization was promoted under non-inductive long days by the removal of buds (Hammes and Beyers, 1973). Menzel (1981) studied the effect of pruning on potato grown under high temperatures and found an increment in tuber weight per plant, and a decrease in haulm weight per plant due to a substantial diversion of dry matter to the tubers. Lambers et al. (2008) showed that decapitation resulted in an increase in the growth rate of the storage root in *Beta vulgaris* and significantly increased the root/shoot ratio. No recent study revealed that flower bud in potatoes can affect either positively or negatively on tuber yield and quality of potatoes.

Therefore, the study was planned to attain the following objectives:

1. To evaluate the effect of flower bud on tuber yield and quality of potato,
2. To differentiate the varieties affected by flower bud factors.

METHODOLOGY

Experimental design and procedures

The trial was conducted at Horo District in Horro Guduru Wollega Zone, Western Ethiopia, located at approximate geographical coordinates of latitude 09°36' N and longitude of 37°12' E at an altitude of 1910 m above sea level. The experiment was laid out in a 2x5 factorial arrangement in a randomized complete block design with three replications. The experiment consisted of two factors vis-à-vis Factor A: Potato cultivars (Beletech, Guduru, Horo, Menagesha, and Jalne) and factor B: Flower bud removal (with and without removal). Each plot had four rows and each row planted with five plants. Experiments was carried out on a plot size of 3 m by 3.2 m = 9.6 m the plot had four rows, and each row had five plants with spacing between rows 70cm and between plants 50 cm.

Plants started to develop flower buds about 45 days after sowing. Therefore, flower buds with two upper younger leaves were removed as soon as they reached a noticeable size. This was done daily by conducting a routine check on each plant in every plot as per the treatment. In a same manner, flower bud removal was continuously checked until four and a half months after sowing (when flowering stopped due to the exhaustion of potential flower buds).

Data collection

The data pertaining to growth, yield and quality was collected from each plot at predetermined schedule from sample plants taken from each plot, with the intention of avoiding/reducing the border effect. Data was collected only from plants found in the middle three rows per plot of each accession. Plant height was measured from the base of the stem to the shoot apex at maturity. A month after the last treatment application, the total leaf area was estimated from the individual leaf length using the formula developed by Firman and Allen (1989). Total tuber yield (t/ha): tuberous root yield taken by measuring the weight of tubers from ten selected plants per plot using a sensitive balance (Bp 16000-s, Germany) and converted to t/ha. Tuber number per hill: tubers per plant count done by counting the number of tubers per plot and dividing by the number of plants per plot. Number of marketable tubers per plant; this was done by counting the marketable tubers per plot and dividing by the number of plants per plot. Number of unmarketable tubers per plant; this was done by counting the unmarketable tubers per plot and dividing by the number of plants per plot. Weight of marketable tubers in tons per hectare; marketable tuberous root yield taken by measuring the weight of tubers from ten selected plants per plot using a sensitive balance (Bp 16000-s, Germany) and converted to t/ha. Number of unmarketable tubers in tons per hectare; unmarketable tuberous root yield taken by measuring the weight of tubers from ten selected plants per plot using a sensitive balance (Bp 16000-s, Germany) and converted to t/ha. Average tuber mass was determined by dividing the total fresh tuber yield by the respective total number of tubers. Tuber specific gravity was determined using weight-in-air and weight-in-water method (Murphy and Goven, 1959). For tuber dry matter content, the tubers were oven dried at a temperature of 72°C to a constant mass. Tuber dry matter content was determined as the ratio

between dry and fresh mass expressed as a percentage.

Data analysis

First, data collected on yield and quality parameters were checked for normality and meeting all ANOVA assumptions. Then the data was subjected to the Analysis of variance (ANOVA) and correlation using SAS statistical package with (SAS 9.3 version, institute Inc., 2012).

Tuber yield is the most complex trait and is influenced by many factors (known and unknown) that determine productivity. Thus, estimations of the magnitude of correlation of tuber yield and its component among yield-related traits are highly crucial to utilize the existing effect of factors LSD used to separate the mean values of the treatments with the significance level of 5%

RESULTS AND DISCUSSION

Analysis of variance

The results of the analysis of variance revealed that potato varieties were significantly different for the character used. In the same way, after the treatment flower bud removal showed a difference for all except in the total number of tubers per hill. This reveal that there is great diversity in the varieties and the flower bud effect is comparatively not much. The interaction of variety and treatment was not statistically different for most of the variables studied. This indicates that the effect of the variety difference does not depend on the treatment used and vice versa. Therefore individual analysis and discussion were crucial for the experiment (Table 1).

Plant height

Non-significant difference was observed between the cultivars regarding plant height (Table 2). However, the pruning treatment significantly reduced plant height compared to the normal growing plants. This is attributed to the direct effect of removal of the growing tip and reduction in stem elongation and increased partitioning of assimilates to the tubers due to reduced GA activity in response to the treatments. Menzel (1980) and Mares et al. (1981) reported that the exogenous application of GA3 inhibited tuber formation, decreased tuber sink strength, and encouraged stem extension. Menzel (1980) and Tekalign and Hammes (2005) reported that the application of GA biosynthesis inhibitors favored the partitioning of more assimilates to tubers by reducing stem extension. Similarly, Benoit et al. (1983) reported that treated plants appeared to be short because of the reduction in stem elongation and increased partitioning of assimilates to the tubers.

Total leaf area

The five cultivars produced incomparable total leaf area

Table 1. Mean Square Analysis of variance for the characters studied.

SV	PH	LA	MTN phil	UnTnp H	TTpH	TYton/hc	MTton /hc	UTton/h c	AvlnTw (g)	DM	SG
df	18	18	18	18	18	18	18	18	18	18	18
var	386.3*	201980*	8.56**	3.2*	18.2**	207.3**	114.9**	34.4**	636.5**	211356*	1.44*
Trt	270.6*	515354*	9.9*	11.8*	0.07 ^{ns}	223.2**	191.7**	27.6**	761.3**	297008*	1.04*
TRT* VAR	27.8	0.02	0.87	0.81	1.02	22.4	14.7	11.2	103*	2.1*	0.14*
Error	36	46	0.96	0.48	0.85	35	19.7	8.9	9.4	1133	0.005
mean	53.4	3134	6.4	3.8	10.2	35.7	24.6	11.02	61.5	3110	2.53
CV%	11.2	1.2	15.3	18.2	9.5	16.7	17.9	18.7	4.9	1.08	2.7

Var-variety, Trt- treatment (flower bud removed and unremoved), TNphil-represents marketable tuber number per hill, TnpHU-unmarketable tuber number per hill, TTnpH-total tuber number per hill, TYton/hc-total tuber yield per hectare in ton, MTton/hc-marketable tuber yield per hectare in ton, UTton/hc-un marketable tuber yield per hectare in ton and AvlnTw/hil(g)- average individual tuber weight per hill in gram.

Table 2. Plant height, total leave area, marketable tuber number per hill, unmarketable tuber number per hill, and total tuber number per hill as affected by varieties and flower bud.

Variety	PH	LA	MTNphi	UnTnpH	TTnpH
Managasha	66.3 ^a	2894 ^d	4.9 ^c	3.4 ^b	8.4 ^c
Guduru	55 ^{ab}	342 ^a	6.6 ^{bc}	3.42 ^b	10.04 ^b
Jalane	51 ^{bc}	3112 ^c	7.1 ^{ac}	4.9 ^a	12.2 ^a
Horo	48.8 ^{bc}	3092 ^c	5.4 ^{dc}	3.15 ^b	8.6 ^c
Beletech	47.5 ^{cd}	3163 ^d	7.9 ^a	3.9 ^{ab}	11.8 ^a
LSD 5%	5.6	44.8	1.1	0.84	1.02
Treatments					
Bud unremoved	56.4 ^a	3002 ^b	5.8 ^b	4.4 ^b	10.27 ^a
Bud removed	50.5 ^b	3265 ^a	6.9 ^a	3.1 ^b	10.3 ^a
LSD 5%	4.6	28.3	0.75	0.53	NS
CV (%)	11.2	1.2	15.3	18.2	9.5

and significant variation in total leaf area per plant (Table 2). This may be due to the genetic constituents of the plant. Treatment also exhibited significant variation in total leaf area per plant. Removal of flower buds encouraged the production of higher total leaf area than unremoved. This could be attributed to the observed high number of lateral branches and expanded leaves in response to pinching of the terminal buds. Shoot apex meristem maintains its role as the primary site of growth by inhibiting the growth of the axillary meristem through the phenomenon called apical dominance and its effect is mediated by auxin levels (Melkamu and Minwelet, 2018). Removing terminal buds stimulated the growth of lateral branches along with the expanded leaves in potato (Tsegaw and Zelleke, 2002; Tekalign and Hammes, 2005). The removal of flower buds gave the lowest total leaf area, resulting in short and compact plants. This response is attributed to the reduction in total leaf area and restriction in stem elongation. Menzel (1981) reported that the most noticeable potato growth response to pruning treatment was the reduction in shoot growth. Higher leaf area is essential for higher

biomass and tuber yield; however, in this study, it has been observed that the treated plants exhibited a higher tuber yield despite the reduced leaf area. This compensation could be due partly to an enhanced net assimilation rate in response to the treatment.

Marketable tuber number per hill

The result from ANOVA revealed that marketable tuber number per hill is highly significant for the varieties and slightly different for flower bud effect (Table 2). This indicates that varieties have their own natural capacity to initiate tuber formation and to store carbon source assimilates in their storage tubers. Similar result was reported by (Bizuayehu, 2008). Even though, the difference is medium, the important variability was observed due to flower bud removal and un-removal. It needs further investigation in multiple locations and years. Tuber development is regulated by an interplay between endogenous and environmental signals and is orchestrated by coordinated and metabolic changes

Table 3. Total number and yield, average tuber mass, tuber specific gravity, and dry matter content as influenced by cultivars and flower bud removal.

Variety	MTton/hc	UTton/hc	AvInTw	TYton/hc
Managasha	21.04 ^b	9.4 ^b	63.8 ^{ab}	30.45 ^c
Guduru	24.5 ^{ba}	15.6^a	53.5 ^c	34.5 ^{cb}
Jalane	26.2 ^{ba}	10.75 ^b	78.9^a	39 ^{ba}
Horo	19.7 ^b	10.7 ^b	52.2 ^c	30.3 ^c
Beletech	29.9 ^a	9.5 ^b	67.5 ^{ba}	44.07^a
LSD 5%	5.3	4.1	2.1	7.2
Treatments				
Bud un removed	22.2 ^b	11.8^a	55.6 ^b	32.6 ^b
Bud removed	27.3 ^a	9.1^b	67.8^a	38.4^a
LSD 5%	3.4	2.4	2.46	4.5
CV%	16.3	8.6	18.7	4.87

(Ferreira et al., 2010). The process controlled by phytohormones including gibberellin (GAs), auxin, and strigolactone (SLs) (Pasare et al., 2013). However, an important trigger comes from environmental cues. In many potato species, short photoperiods favour tuber initiation, while high temperatures (especially during the night) and high nitrogen levels are inhibitory (Abelenda et al., 2011). Under favorable conditions, a mobile tuberisation signal is produced in the leaves and is then transported to the stolons, inducing tuber formation. For this study, variety Beletech and Jalane record the heights and number of marketable tubers per hill (7.9 and 7.1), respectively (Table 2). The smallest number of marketable tubers per hill was recorded by variety Menagesha (4.9). In the case of treatment, with flower bud removal and un- removal, treatment with flower bud removed records more marketable tuber numbers per hill compared to the un-removals. Similar outcome on the effects of above ground bud removal and storage roots and tubers were reported by different authors. Menzel (1981) studied the effect of pruning on potatoes grown under high temperatures and found an increment in tuber weight per plant, and a decrease in haulm weight per plant due to a substantial diversion of dry matter to the tubers. Menzel (1981) showed that decapitation resulted in an increase in the growth rate of the storage root in *Beta vulgaris* and significantly increased the root/shoot ratio.

Number of un-marketable tubers per hill

ANOVA showed statistically differences between varieties and on the flower bud effect. Interaction between variety and flower bud effect is not significant. Variety Jalane ranks first in the number of unmarketable tubers per hill (4.9) which was ranked first in the number of marketable tubers per hill. Variety Horro recorded the list (3.1) (Table 2). This tale is, some cultivars initiate

tuberization when the condition is favored but able to attain quality tuber size dueto several factors as environmental and or biotic. Generally, a high number of un-marketable tubers was obtained from the treatment flower bud was not removed compared to removed (3.1 and 4.4 respectively) (Table 2). This result was in line with some other results in different areas. The increase in average tubers, as a consequence of the removal of buds and younger leaves, may be explained on the basis of the absence of competition for assimilates between shoots and tubers. It is speculated that, in the absence of buds and younger leaves, presumably since developing tubers are the predominant sinks, a large amount of dry matter is diverted to the tubers, which would otherwise be utilized for shoot growth. As a result, most of the initiated tubers increased in size (Tekalign and Hammes, 2005). Similarly, Menzel (1981) reported that the removal of buds and younger leaves caused a substantial diversion of assimilates to tubers and thereby increased tuber size (mass) and the number of tubers.

Total tuber number per hill

Significant ($p < 0.01$) differences in tuber number per plant between varieties were observed. However, the difference in tuber number per plant in response to flower bud removal and their interaction was not significant ($p > 0.05$) (Table 2). Data presented in Table 3 depict that the highest number of tuber number was found in variety jalane (12.2) followed by Beletech (11.8) and the lowest total tuber number per hill was recorded in variety menagesha (8.4). The difference in root number between accessions might be the output of genotypic variation among accessions.

Nevertheless, flower bud removal had no marked influence on tuber number per plant. Possibly, this happened because the flower bud removal cannot

influence the genetic potential of the crop. That is, if one cultivar is meant to produce four tubers per plant, the treatment does not have the role to add more number of roots and tubers. In addition, the physiological activities of tuberization started before flower bud commencement. The issue was further explained by (Tsegaw and Zelleke, 2002), the variation in the total number of tubers of potato among treated (reproductive pruning) plants were not significant.

Tuber yield

The mean total tuber yield (marketable and un-marketable) revealed statistically different for variety and flower bud effect. Highest tuber yield was recorded from variety Beletech (44.07 tons per hectare) followed by variety Jalene (39.87 tons per hectare) (Table 3). In contrast, the smallest total tuber yield in ton per hectare was measured from variety Horro (30.3). Moreover, the total tuber yield per hectare showed high correlation with the marketable tuber yield in tone per hectare, i.e., similar varieties recorded the same rank of total tuber yield in total marketable yield. In other words, the total marketable yield provides positive contributions to the overall tuber yield. The effects of flower bud depicted significant variation within and between the varieties. Varieties which record high marketable tubers per hill may fall under the group of high unmarketable tuber yield per hectare due to not removed flower buds. For instance, in variety Jalene, both the highest total tuber per hill and the highest total un-marketable yield per hectare were measured. This tale is, some cultivars initiate tuberization when the condition is favored but able to attain quality tuber size due to several factors such as environmental highest shoot to root/tuber ratio and or biotic problems encountered during storage organ accumulation. For the general mean yield, the highest marketable tuber yield was recorded from flower buds removed (27.3ton per hectare) compared to unremoved (22.2 tons per hectare). However, the largest unmarketable tuber per hectare (11.8 tons per hectare) recorded from the treatment flower but was not removed. From this, we observe that flower bud removal can increase tuber size and then the total tuber yield in relation to unremoved. This result showed relativity with the result of Tekalign and Hammes (2005) and Pasare et al. (2013). It is speculated that, in the absence of buds and younger leaves, presumably since developing tubers are the predominant sinks, a large amount of dry matter is diverted to the tubers, which would otherwise be utilized for shoot growth. As a result, most of the initiated tubers increased in size (Tekalign and Hammes, 2005). Similarly, Degebase (2019) reported that the removal of buds and younger leaves caused a substantial diversion of assimilates to tubers and thereby increased tuber size (mass) and the

number of tubers.

Average individual tuber weight per hill

This was one of the characters, which reveals good variability either in varieties or on the effect of flower bud on tuber yield in potatoes. Varieties showed highly significant differences between each and within the variables. Similarly, the effect of flower bud also showed significance differences between the varieties and within the treatments. The interaction of variety and flower bud effect was not significantly different. This indicates that the effects of flowers have variability with individual tuber size or weight and between varieties. Variety Menagesh records the highest individual tuber weight (78.9g) followed by Beletech (67.5g) (Table 3). The general individual tuber weight told as treatments which removed flower buds produce weighed tubers (67.8) compared to unremoved (55.2 g) in average (Table 3). This result is also synonym with (Tekalign and Hammes, 2005) and Menzel (1981) reports. In the plant, the amount of assimilates partitioned in the organ depends upon its sink strength which is a competitive ability to attract assimilates (Akash. 2019).

Specific gravity and dry matter content

It is often necessary to know the dry matter content of potatoes since this largely governs the weight of processed products which can be obtained from a given weight of raw tubers. It is also one of the main determinants of quality, both for processing and for cooking. High dry matter content has been reported to be desirable because of less sugar accumulation and water content. Storey and Davies (1992) observed that tubers with high dry matter content required less energy input during frying or dehydration to remove water; this resulted in greater product yield per unit fresh weight than tubers with lower solid content and absorbed less oil during frying. Specific gravity could also be measured using Potato Hydrometer as Storey and Davies (1992) method, but measured as the ratio of weight in air and weight in water.

There was a significant difference in tuber specific gravity and dry matter content between the five cultivars and between the two treatments. The interaction between cultivars and treatments also showed significant differences (Table 4). Variety Beletech interacting with bud removal records the highest (18.13%) and (1.51) in dry matter content in percentage and specific gravity, respectively. In contrast, the variety Guduru and Jalane interaction with bud removal record the least (13.5%) and (1.05) in dry matter content in percentage and specific gravity, respectively (Table 4). This indicates the five cultivars respond differently to flower bud

Table 4. Variety*Treatment interaction effect on dry matter in percentage and specific gravity.

Variety	Treatments			
	DM%		SG	
	Bud not removed	Bud removed	Bud not removed	Bud removed
Managasha	11.7 ^{ef}	13 ^{df}	1.04 ^e	1.24 ^{bc}
Guduru	11.8 ^f	13.5 ^d	1.1 ^{de}	1.33 ^b
Jalane	16.1 ^b	18.5 ^a	1.5 ^a	1.05 ^e
Horo	12.4 ^{bc}	14.6 ^c	1.24 ^c	1.3 ^{bc}
Beletech	18.1 ^a	18.13 ^a	1.2 ^{cd}	1.51 ^a
LSD 5%	0.8		0.11	
CV%	3.31		5.55	

removal for these quality parameters. Therefore, it needs further investigation by increasing pruning frequency, environments, and season of growth. Compared to unremoved, the removal of flower buds with two upper younger leaves significantly influence specific gravity and dry matter content. Accordingly, the removal of flower buds with two upper younger leaves increased specific gravity by about 1.6% and dry matter content by about 9.5% compared to the unremoved. This could be due to a high concentration of GA which reduces the diversion of assimilates to the tubers and decreases starch accumulation. This study is in line with Booth and Lovell (1972) who explained that the application of GA3 to potato shoots reduced the export of photosynthates to the tubers, decreased starch accumulation, increased sugar levels and resulted in the cessation of tuber growth. Improvement in tuber specific gravity as well as dry matter content in response to the pruning treatments may be due to the diversion of the largest proportion of assimilates to the tubers due to reduced GA activity that would be used for excessive top growth. This finding is supported by Menzel (1981) who reported that the largest proportion of assimilates were diverted to the tubers and enhanced starch synthesis after removing buds and younger leaves. Similarly, Tekalign and Hammes (2005) observed an increased tuber specific gravity and dry matter content in response to paclobutrazol (GA biosynthesis inhibitor) which may be due to an increased sink strength to attract more assimilates and enhance starch synthesis. Highly significant positive correlation ($r = 0.65^{**}$) was observed between specific gravity and the percentage of dry matter, indicating that specific gravity is a true indicator of the amount of dry matter (total solid) of tubers. In agreement with the present study, Tsegaw and Zelleke (2002) reported a highly significant positive correlation between specific gravity and the percentage of dry matter.

Character association

Tuber yield is the most complex trait and is influenced by

many factors (known and unknown) that determine productivity. Thus, estimations of the magnitudes of genotypic and phenotypic correlations of tuber yield and its component among yield-related traits are highly crucial to utilize the existing effect of these factors.

The association of most of the characters showed positive correlation to each other unless for total marketable tubers per hill and total un-marketable tubers per hill, average individual tuber weight per hill and total unmarketable tuber number per hill, and average individual tuber weight per hill and total tuber number per hill (Table 5). This indicates that as the number of tubers per hill increases, the total assimilated storage per tuber decreases. This can reduce the marketable tuber yield and the total yield. This association result was similar to the result of Sandana and Kalazich (2015). The total tuber yield showed a strong positive correlation with the number of marketable tubers per hill, total tuber number per hill, marketable tuber yield, and average individual tuber weight per hill. Similarly, it showed weak positive association with others like number of unmarketable tubers per hill and total un-marketable yield. Akash (2019) reported, dry matter and specific gravity correlated in high positive to each other and with average individual tuber weight, total yield, and marketable tuber yield. In this regard, for the improvement of total yield in potatoes, it is agronomically important to favor the growing condition of traits that are positively associated with it and disfavor for traits, which are negatively associated with tuber yield. Moreover, it is advisable to differentiate either of the direct or indirect associations of this trait.

Conclusion

Breeders, genetics, biotechnologists, and agronomists intervene in the natural system of plant development for improving the quantitative and quality of the economically important traits of natural plants. As Irish potato is one of the primary food items in the world, and threatened by different factors including biotic and

Table 5. Character association for the trait under study.

Variable	TNphillm	TNhilun	Ttphill	Avgg	Ytonhac	Mtytoh a	Umt y ha	DM	SG
TNphillm									
TNhilun	-0.17*								
Ttphill	0.75**	0.58**							
Avgg	0.079	-0.16*	-0.29						
Ytonhac	0.62**	0.126	0.59*	0.27*					
Mtytohac	0.61**	0.159	0.54**	0.23	0.88**				
Umt y hac	0.29	0.082	0.29	0.084	0.36*	0.27			
DM	-0.21	-0.23	0.06	0.54*	0.39	0.23	-0.13		
SG	0.33	-0.05	0.11	0.49*	0.46*	0.21	-0.12	0.65**	

**, * indicates highly significant and significant correlation of the traits.

abiotic factors, researchers devote much of their time to develop more improved potato varieties in different aspects. In this experiment, the idea of improving tuber product through flower bud removal is proposed. The result of ANOVA depicts there was highly significant variation ($P < 0.01$) between the five varieties studied in all aspects of the trait analyzed. For the second factor, flower bud removal and un-removal, all traits showed significant difference ($P < 0.05$) except the total number of tubers per hill. However, the interaction of the two factors, variety and flower bud showed nonsignificant variation except for dry matter content and specific gravity. This indicates, as two of the factors are undependable of each other except for a few variables. Whatever the result of this experiment, the study needs further investigations in different environments' and years to attain conclusion.

Most of the characters showed positive correlation to each other unless for total marketable tubers per hill and total un-marketable tubers per hill, average individual tuber weight per hill and total unmarketable tuber number per hill, and average individual tuber weight per hill and total tuber number per hill. This indicates that as the number of tubers per hill increases, the total assimilated storage per tuber decreases. In this regard, for the improvement of total yield in potatoes, it is agronomically important to favor the growing condition of traits that are positively associated with it and disfavor for traits, which are negatively associated with tuber yield. Moreover, it is advisable to differentiate either of the direct or indirect associations of this trait.

Recommendation

The present study was confounded due to several limitations including financial and time resources; it would be pertinent to recommend this salient point for further study.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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