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Determination of Optimum Planting Date and Resistant Varieties of Potato (*Solanum Tubersum*) to the Reaction of Late Blight (*Phytophthora Infestans*) Disease at Chencha, Southeastern Ethiopia

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Abstract **– Potato (*Solanum tubersum* L.) is the most commonly cultivated crop throughout the world thought it has been constrained by various biotic and a_biotic factors. Among, potato late blight disease is the major one and caused millions to be hunger. Study was conducted to identify the resistance variety and optimum planting date to the reaction of late blight disease at Chencha, Southeast Ethiopia. Three improved varieties (Belete, Jalene, Gudene) and one local cultivar with three planting dates (Feb. 20/2015, Feb. 30/2015 and March 10/2015) were examined in split plot design. Planting dates were considered as the main factor whereas varieties are as sub-plot factor. The results showed that stand count and days to 50% flowering were not significantly affected by interaction and varietal effect but, it was affected by planting date. All yield and yield related traits as well as diseases severity were showed highly significant variation on both factors, except the interaction. The maximum (54.26 t/ha) and minimum (37 t/ha) marketable yield was obtained from Belete and local cultivar respectively. Whereas, the maximum (59.22 t/ha) and minimum (24.16 t/ha) marketable yield was demonstrated from planting date Feb. 30 and Feb. 20/2015 respectively. Jalenie was identified as susceptible variety with disease severity score (77%) where as Gudene was moderately resistance with disease severity score (59.42%). The highest disease severity (92.22%) was recorded in Feb. 30 whereas the least (47.66) was demonstrated in March 10/2015. Therefore, it is advisable to producers around the study area should have to cultivate Belete variety in Feb. 30 planting date. Further research with different growing season and years are crucial for sound results and recommendations.**

Keywords **– Disease Severity, Late Blight, Planting Date, Potato and Varieties**

I. Introduction

Potato late blight (*Phytophthora infestans)* is the most destructive and serious potato disease in worldwide [1]. The average global potato crop losses in developed countries was estimated to 21.8% but, this figure was much higher for developing countries [21]. It is a very serious economic threat in the vast majority of potato production systems and worldwide losses are estimated to exceed $5 billion annually and thus the pathogen is regarded as a threat to global food security [22]. The most severe damage of the disease for both economic and social impact was best illustrated by the well-publicized role it played in the Irish Famine in the middle of the 19th century causing millions of Irish people died and/or emigrated. The disease also affects tomatoes and some other members of the family solanaceae [23],[10] and[1]).

In Ethiopia late blight is the most destructive diseases of potato and tomato. It caused 100% potato crop losses on unimproved cultivar, and 30–75% on a susceptible variety [5], [14] and [18]. Some researchers also reported of estimated losses ranging from 6.5 to 61.7%, based on susceptibility of the varieties [11] and [8]. The disease could occur at any time during the growing season and more common in the area where potato is highly produced. It is the most devastating disease in developing countries like Ethiopia where producers do not have know how about the epidemiology and controlling methods of the disease. In Ethiopia, the disease occurs throughout the major potato production areas such as Central Ethiopia, Eastern Harerge, Northwest Ethiopia, South and Western Ethiopia. It is more likely to be seen in late summer and early autumn [7], [16], [5] and [14].

Integrated pest management practices is the crucial task to control the severity of late blight disease and was adopted in Ethiopia over the past 10 years ago as a strategy. Among the strategies, epidemiology resistance and late planting are considered as most important though minimum applications of fungicides have both advantages and disadvantages. As [22] reported plots with late planted potato could yield 50% and 75% more than early planted potato and the use of host plant resistance for late blight has received considerable attention in many countries of Sub-Saharan Africa. On the other hand, [26] also reported that spraying fungicide every 5 to 10 days after the vines reach 15-30cm is an important management practices of late blight disease. However, the use of chemicals could result in environmental pollution and climate change as well as eradication of important insects. Hence, it is better to use host resistance variety and right planting time which are cost effective and environmentally friendly. In Ethiopia, 29 varieties of potato have been released in collaboration with EIAR (Ethiopian Institute of Agricultural Research)-CIP (International Potato Center) breeding program [27]. Holeta Agricultural Research Center also categorized potatoes into three varieties according to their resistance level in 2006. Proper planting date for potato varieties has been considered as a crucial in order to avoid period of heavy late blight infection [15]. The present study was conducted to determine resistance variety and optimum planting date for the reaction of late blight diseases at Chencha, Southeastern Ethiopia.

II. Materials and Method

Description of Study Site

The experiment was conducted at Chencha, Gamo Gofa, Southeastern Ethiopia during 2015 cropping season. The area was located at 37° 6' E and 6° 13' N, at an altitude of 2,600 to 3,005 m.a.s.l with a mean annual rainfall of 1,500 mm and 26°C and 8°C mean maximum and minimum temperature. The soil characterized by pH ranges from 4.8 to 6.7 with clay loam property [30].

Treatments

Three improved potato varieties (Belete, Gudene and Jalene) were collected from Holeta Agricultural Research Center and one local cultivar was obtained from Chencha Farmers' Training Center (FTC) to determine the capability of resistance to late blight disease. Three planting dates (Feb., 20/2015, Feb., 30/2015 and March, 10/2015) were identified based on farmers' practice and late blight disease outbreak profile (Chencha Woreda Agricultural Bureau, unpublished). In each planting time, the experimental sites were well prepared and recommended fertilizer (DAP and UREA) rate were added during planting time [2]. All recommended agronomic practices were implemented throughout the experimental season.

Table I. Passport data for three varieties

No.	Variety or genotype	Accession code	Year of release	Yield (t/ha)	Recommended Altitude (meters above sea level)
1	Belete	CIP-393371.58	2009	47.2	1600-2800
2	Gudanie	CIP-386423.13	2006	29.0	1600-2800
3	Jalanie	CIP-37792-5	2002	40.3	1600-2900

Source: [25]

Experimental Design

The experiment was laid out in split plot design with four replications. Three planting dates were considered as main plot and four varieties were as sub-plot factor. The gross plot size 3m x 3m (9m^2) was used for each experiment. The gross experimental area 15m x 16.5m (247.5m^2) was used for each experimental time. Hence, sixteen plots were randomly assigned in each experimental area and ten plants were planted in each row with total number of forty plants per plot. Each plot contained four rows that the middle two rows were selected for sampling. Nationally recommended plant spacing such as 30cm between plants and 60cm between rows were used for each planting time.

Disease Severity Assessment

Disease severity was measured based on *Pictorial key* method according to (Little and Hills 1978, cited by [12]) model. By angular transformation, a 7-point rating scale was created. Disease severity was estimated by comparing late blight diseased leaf with a modified pictorial key. The rating was made by picture most closely matching leaf damage, from 0 = no disease to 6 = more than 93% diseased. The average value from the sample plant was done for final calculation. Data analysis was done on the transformed ratings then back transformed to obtained percent values. To calculate, the following formulas were used according to [12] report.

$DRP = \sum DRL/Lvs$

$HLvs = 6 - DRPBT\% \times Lvs$

Where:

DRP = Estimated disease rating per plant (0-6).

DRL = Estimated disease rating per leaf.

Lvs = Number of leaves per plant.

BT% = Rating back transformed to a percentage;

HLvs = Effective number of healthy leaves perplant

Data Collection and Analysis

Ten plants were identified from the middle rows for sampling. Growth parameters such as, stand count (SC), days to fifty percent of flowering (DFPF), number of main stems (NS); yield and yield components (number of tubers per plant (TPP), marketable tuber yield (MTY), unmarketable tuber yield (UMTY) and total tuber yield (TTY) and disease severity were determined. Days to fifty percent of flowering (DFPF) was recorded when fifty percent of population in each plot were bloom so as to determine the maturity period of varieties. Number of main stems, number of tubers per plant, marketable, unmarketable and total tuber yields were collected at harvesting time; but, disease score such as disease severity was collected twice a week began after 40 days of planting and then, continued till harvest. Tubers were carefully collected after the hills were dug by dibber (back hoe). The collected total tubers in each plot were weighted and converted to tons per hectare (t/ha). Tubers which were free from diseases, insect pests attack, and greater than or equal to 20 g in weight were sorted, weighed and considered as marketable yield. The remaining tubers were considered as unmarketable yield, [20]. In each disease sampling period, diseased plants from the middle rows were sampled and disease pathogen was grown at Arbaminch plant clinic laboratory for screening. After harvesting pathogen from tubers and above ground plant parts were subjected to grow in different peter dish with similar growing media though pathogen was not observed in growing media where tubers were allowed to be source of sample. Mean values of disease severity were subjected to repeated measures of Analysis of Variance (ANOVA) to evaluate treatments effect. Yield and yield component data were subjected to analysis by SAS (Statistical Analysis System) software version 9.3. Least Significant Difference test at 5% significance level (LSD 5%) was used to determine the treatment mean differences.

III. Result and Discussion

Yield Related Parameters

The analysis of variance for stand count and days to 50% flowering revealed that there were no significant variation among varieties at (*P*<0.05). On the hand, there were statistically significant differences in planting date regarding with stated parameters (Table 3). Number of main stems per plant was significantly affected by both main and simple effect of varieties and planting dates (p<0.05). However, the interaction effect of both varieties and planting date was insignificant. The maximum stand count and days to 50% flowering were exhibited at planting date two (Feb. 20/2015) though there were no significant variation at planting date one (Feb. 10/2015). This could be due to favorable weather condition for plant growth and development which fasten potato to bloom early. The maximum number of main stems per plant was recorded from Jalene (4.7) and planting date three (4.9). The current finding is also in harmony with [24] who reported that Jalene variety produced the highest number of stems (4.5) per plant compared with Belete, Gudene and local. [2] Also postulated that stem number not only affected by genotypes and planting date but also plant densities. Therefore, the ability of genotypes to produce multiple stem can be affected by environment (planting date), agronomic practice (plant densities) and genotypes.

Table II. Mean square values for tuber yield and yield related traits as affected by varieties and planting date to the reaction of late blight disease of potato at Chencha, in2015

Source of variation	DF	Mean squares DFPF	NS	NTPP	MTY	UMTY	TTY
Rep	3	171.5^{ns}	0.41^{ns}	9.6^{ns}	6606.5^{ns}	833.7^{ns}	11396.6^{ns}
Variety	3	185.13^{ns}	2.3^{ns}	12.98^{ns}	70215.8*	2894.8**	83376.6**
Rep *x* var	9	287^{ns}	1.45^{ns}	8.04^{ns}	7560.7^{ns}	528.9^{ns}	7788.6^{ns}
P.date	2	973*	13.8**	33.7*	500451.2**	14662.3**	637446**
P.date x var	6	114.6^{ns}	1.7^{ns}	9.9^{ns}	27781.2^{ns}	955^{ns}	35490.3^{ns}
Error	24	257.26	0.8	9	15130.73	611.9	16606
$Cv_{(\%)}$		25	21.6	25.4	28.56	59.1	27.2

- ns, *, ** non-significant, significant (5%) and highly significant (1%).
- DF = (Degrees of freedom), Rep = (Replications), P. date = (Planting dates) Var = (varieties), DFPF = (days to 50% flowering), NS = (Number of suckers), NTPP = (Number of tubers per plant) MTY = (Marketable tuber yield), UMTY = (Unmarketable tuber yield) and TTY = (Total tuber yield).

Table III. Effect of planting date and varieties on stand count (SC), days to 50% flowering (DFPF) and main stem number (SN) of potato at Chencha, in 2015.

Varieties	Growth parameters SC	DFPF	SN
Belete	33.00	64.83	4.17^{ab}
Jalene	31.58	67.16	4.77^{a}
Gudene	32.750	60.83	3.84^{b}
Local	33.58	58.41	3.85^{b}
LSD (0.05)	NS	NS	0.82
Planting date			
1	30.81^{b}	67.06^{a}	3.11^{b}
2	35.87^{a}	67.56^{a}	4.46^{a}
3	31.50^{b}	53.81^{b}	4.9^{a}
LSD	4.22	11.7	0.71
CV (%)	17.9	15.7	12.1

Disease Severity

The result of the current study indicated that there were highly significant difference between varieties and planting date of potato (p<0.01) regarding to late blight disease severity. But, the interaction effect of varieties and planting date were statistically insignificant. The severity range was recognized from 59.64 to 77% hence, Jalenie variety identified as leaf susceptible though statistically identical with Belete and local. Gudene variety was identified as moderately resistance variety with disease severity 59.64% (Fig. 1). The results of the present study is in disagreement with that of [2] who reported that Belete and Gudenie varieties were resistance (13%) and moderately (40) resistance to late blight respectively but, Jalenie was reported as susceptible (60%) variety. [29] Also found Jalenie variety as a resistance with resistance rate of 1 where as Gudene variety was identified as moderately resistance variety. This variation in resistance to the disease could be due to variation in aggressiveness of the pathogen races and environment (micro-climate) variation of experimental site. Hence, the highest sporangia can be produced at temperature ranged 8.5 to 26^{o}C and the optimum ambient humidity for abundant formation ranges 90-100%. The sporulation highly enhanced with high humidity around the foliage [3].

The highest disease severity (92.27%) was determined at planting date two (Feb. 30/2015) whereas the least (47.66%) disease severity was from planting date three (March 10/2015) (Fig. 2.). Determining the favorable time at which the pathogen can develop and spread is the crucial task for appropriate management of late blight disease and hence, Feb. 30/2015 was considered as the time for disease development. This might be highly related with temperature, humidity and day length of the study area. As [3] reported the production and development of Sporangia are highly related with these environmental factors. On the other hand, the least severity (47.6%) at March 30/2015 could be due to unfavorable conditions for the development of pathogen, i.e., low relative humidity (bellow 85%), high temperature, low precipitation pattern and inactive pathogen [17].

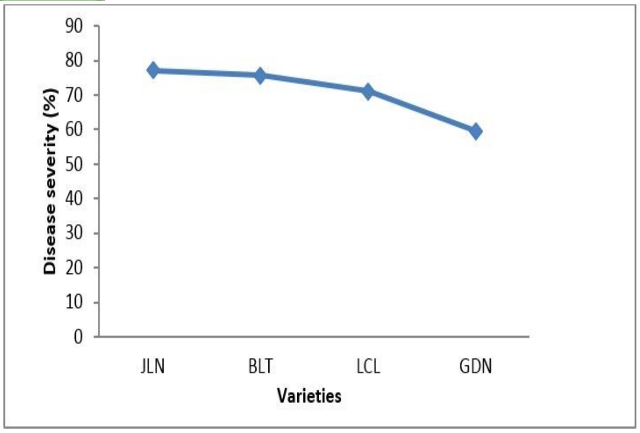

Fig. 1. Performance of potato varieties for the reaction of late blight severity; JLN = (Jalenie), BLT = (Belete), LCL = (local cultivar) and GDN = (Gudenie)

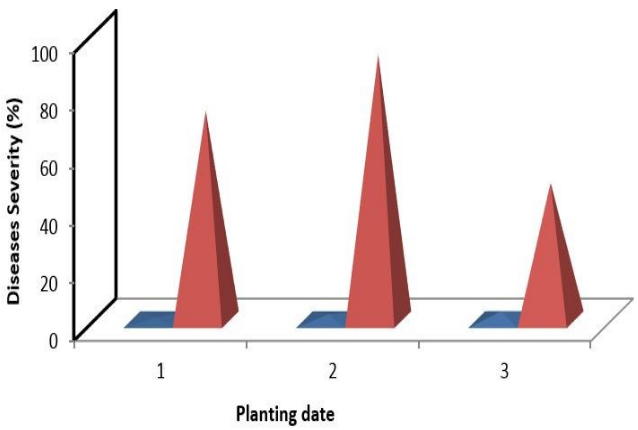

Fig. 2. Late blight severity on potato varieties at different planting date at Chencha in 2015; 1 = (Feb., 20/2015), 2 = (Feb., 30/2015) and 3 = (March, 10/2015)

Yield Parameters

The study showed that all yield parameters such as marketable, unmarketable and total tuber yield were highly affected by both main and simple effect of varieties and planting date ($P<0.01$) whereas, the LSD (5%) result showed no significant different among varieties on number of tubers per plant rather than planting date showed statistically significant different ($p<0.05$). The highest marketable tuber yield (54.26 t/ha), unmarketable tuber yield (5.74 t/ha) and total tuber yield (58.85 t/ha) were recorded from Belete, Gudenie and Belete respectively; whereas, the least total tuber yield (39t/ha) was obtained from local cultivar. In contrary, [24] was reported Gudenie as a high yielder (38.52 t/ha) cultivar followed by CIP-384321/3B genotype (37.33t/ha). The variation could be due to environmental factor that different varieties have different environmental requirement to perform well. [30] Reported similar results with the current result that Belete variety considered as the high yielder following Jalenie and Gudenie. The variation in unmarketable could be due to undersized/oversized, wounded, bruised and insect (worms) invasion factor. Because, both laboratory and correlation result showed tubers are not affected by late blight disease. This might be due to some varieties have useful foliage resistance but poor tuber-blight resistance. Yet, others have good tuber-blight resistance but, poor foliage-blight resistance (Anonymous 2007, cited by [8]).

In case of planting date effect on marketable, unmarketable, total tuber yield and number of tubers per plant was showed significant variation (Table IV). The total tuber yield ranged from 25.13t/ha (planting date one) to 63.88t/ha (planting date two). This could be due to conducive environmental factors for potato development and tuberization. When the temperature exceeds 22°C, tuberization process will be decreased and therefore, yield reduction can be resulted. This result also agrees with that of [13] who reported that different varieties showed significantly different tuber yield. Unmarketable tuber yield was ranged from 0.95 t/ha (planting date three) to 6.94t/ha (planting date one). This may resulted from small tuber size and /or large tuber size as well as insect affected and wounded. The late blight disease factor was not recognized and therefore ignored.

Table IV.Tuber yield and yield related characters as affected by varieties and planting date of potato at Chencha in 2015

Varieties	NTPP	MTY (t/ha)	UMTY (t/ha)	TTY (t/ha)
Belete	11.05^{a}	54.26^{a}	4.59^{a}	58.85^{a}
Gudene	10.73^{a}	40.7^{b}	5.74^{a}	46^{b}
Jalene	12.58^{a}	40.26^{b}	4.37^{ab}	45^{b}
Local	12.76^{a}	37^{b}	2.04^{b}	39^{b}
$LSD_{(0.05)}$	NS	10.36	2.08	10.86
Planting date				
1	10.163^{c}	24.16^{c}	6.94^{a}	25.13^{c}
2	12.22^{ab}	59.22^{a}	4.66^{b}	63.88^{a}
3	12.96^{a}	45.77^{b}	0.95^{c}	52.72^{b}
$LSD_{(0.05)}$	2.18	8.97	1.8	9.4
$CV_{(\%)}$	25.45	28.56	59.1	27.27

- Means with the same letters within same column are not significantly different at 5% probability level
- NTPP=(Number of tubers per plant) MTY= (Marketable tuber yield quintal per hectare), UMTY=(Unmarketable tuber yield) and TTY=(Total tuber yield)

Correlation

The correlation analysis revealed that there were high and positive association between marketable yield with number of main stems ($r = 0.48^{**}$) and tuber per plant ($r = 0.29^{*}$) (Table V). This showed that marketable yield and total tuber yield was increased as a factor of both stem numbers and tubers per plant. On the other hand, unmarketable tuber yield was highly and negatively related with disease incidence ($r = -0.41^{**}$). This implies that unmarketable yield was due to other internal and/or external factor other than, late blight disease. All yield and yield related factors were not significantly associated with disease severity, but, number of main stems negatively correlated though statistically the relation was not significant ($r = 0.07429$).

Table V. Correlation coefficient for yield and yield related variables and late blight disease severity at Chencha (2015).

	SC	NS	TPP	MTY	UNMTY	TTY	DS
SC	1	0.328*	0.385**	0.53**	0.047	0.48**	0.267
NS		1	0.409**	0.48**	0.439**	0.51**	-0.07429
TPP			1	0.29*	0.214	0.305*	0.14555
MTY				1	0.49**	0.98**	0.18461
UNMTY					1	0.62**	-0.41**
TTY						1	0.096
DS							1

SC= stand count, NS= number of suckers, TTP= Tubers per plant, MTY= marketable tuber yield, TTY= Total tuber yield and DS = disease severity.

IV. Conclusion

Potato is world-wide and food securing crop which commonly cultivated throughout the world. But, it is highly constrained with different biotic and a biotic factors. Late blight disease is one of the main limiting factor and caused millions to be hunger. This critical issue needs quick responses and multiple management tactics. One of the tactic therefore, identification of resistance varieties and optimum planting date for inhibition of the disease outbreak and also minimize its severity.

The current study identified Belete variety as a high tuber yielder (58.85t/ha) at optimum planting date of Feb. 30-March 10. Though, the severity of the disease was high at stated time, the yield in this case, tuber was not affected. The late planting date (March/1) also possibly appropriate planting time with minimized late blight severity and hence, producers should have to practice those identified variety with both planting dates to have minimized disease reaction and high tuber yield.

Further study on the same title with various production seasons and years are crucial for accurate result; because, climate is changing with varying environmental factors (temperature, humidity and precipitation). Additional research on integrated disease management for the study area also advisable to have multiple choices for growers.

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