Exploring the Potential for Sustainable Potatoes as a Crop for Northern Ghana

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Received:- 12 September 2024/ Revised:- 18 September 2024/ Accepted:- 26 September 2024/ Published: 30-09-2024

Abstract— *The Irish potato (**Solanum tuberosum**) belongs to the solanaceae family of flowering plants. It is a staple food in many parts of the world and an integral part of much of the world's food supply. The Irish potato is a critical crop in terms of food security in the face of population growth and increased hunger rates. Despite the potential for the potato as an important food and income security crop, very little effort has been made in Ghana to adopt and integrate it into the food production system. It is against this backdrop, that this study was designed to investigate the potential for introducing Irish potatoes as a new crop for Ghana. In this study, certified seed of three Irish potato varieties (Maris Peer, Mayan Rose and Nadine) was imported from Scotland (UK) and planted in July under rainfed conditions. The study was implemented in a four-block randomized complete block design in three replicate sites in the northern region (Nebilyili, Yapalsi and Wulensi). The planting was done on both ridges and on flat land. The crops were monitored till harvesting. Generally, the yield was poor, with a maximum of 3.1MT/ha. Among the varieties, Nadine performed better than Mayan Rose and Maris Peer, although there was no significant difference (P > 0.05) between varieties. Among the three sites that were used for the trial, there was significant difference (P < 0.05) between Wulensi and the other two sites with the Wulensi site performing better. There was also no significant difference in yield between potato planted on ridges and those planted on flat land. Fungal species belonging to the genera Aspergillus, Fusarium and Penicillium were isolated from the healthy and rotten Irish potato tubers. Also, fungal species belonging to Alternaria, Aspergillus, Fusarium, Mucor, Penicillium and Trichoderma were isolated from the root system of the Irish potato crops. Based on the findings, we conclude that, Irish Potato can be grown as a food crop in Ghana, if the necessary agronomic conditions are provided.*

Keywords— Irish Potato, Exploring, Potential, Food security, Northern Ghana, fungi.

I. INTRODUCTION

The potato (*Solanum tuberosum*) belongs to the Solanaceae family of flowering plants. First domesticated in the Andes mountains of South America, it is a staple food in many parts of the world and an integral part of much of the world's food supply (Spooner et al., 2014). The potato is the world's most important root and tuber crop. It is grown in more than 125 countries and consumed almost daily by more than a billion people (FAO, 2019). Hundreds of millions of people in developing countries depend on potatoes for their survival. Potato cultivation is expanding strongly in the developing world, where the potato's ease of cultivation and nutritive content have made it a valuable food security and cash crop for millions of farmers. Developing countries are now the world's biggest producers and importers of potatoes and potato products (FAO, 2009). As of 2014, potatoes were the world's 4th most consumed food crop after maize, wheat, and rice (CIP, 2019; Johnson & Cheein, 2023.). Potato is a critical crop in terms of food security in the face of population growth and increased hunger rates (CIP, 2019).

Potatoes yield abundantly with little effort, and adapt readily to diverse climates as long as the climate is cool and moist enough for the plants to gather sufficient water from the soil to form the starchy tubers (Ensminger et al., 1994). One hectare of potato can yield two to four times the food quantity of grain crops. Potatoes produce more food per unit of water than any other major crop and are up to seven times more efficient in using water than cereals (CIP, 2019). The yield of calories per acre (about 9.2

million) is higher than that of maize (7.5 million), rice (7.4 million), wheat (3 million), or soybean (2.8 million) (Adepoju et al., 2010, Ensminger & Ensminger., 1994).

Today, potato production and consumption are booming worldwide, with ever greater quantities being processed for the convenience food and snack industries, while its importance as a subsistence crop continues to expand. Many developing countries are eager to enter the lucrative emerging markets for potatoes and potato products, but to do so needs a major assessment of the productivity, profitability and sustainability of their potato subsectors. For example, potato yields in the developing world average around 10 to 15 tonnes per hectare, less than half of the average yields achieved by farmers in Western Europe and North America (FAO, 2009).

The development of a vibrant, profitable and sustainable potato subsector in developing countries depends on measures to overcome a number of persistent constraints. Those measures include improvements in the quality of planting material, potato varieties that have reduced water needs, greater resistance to insect pests and diseases, and resilience in the face of climate changes, and farming systems that make more sustainable use of natural resources (FAO, 2009).

Despite the potential for the potato as an important food and income security crop in developing countries and the eagerness of many developing countries in adopting and integrating potatoes into their crop production systems, no such effort has been made in Ghana, despite the fact that, there are visible food and income security challenges in the country (Darfour and Rosentrater, 2016).

It is against this backdrop, that this 18-month feasibility study was designed to investigate the potential for introducing Irish potatoes as a new crop to northern Ghana, and to the country at large. In this study, to maximize the chances of success we used novel seed potato varieties (Maris Peer, Mayan Rose and Nadine) developed by the Sarvari Research Trust, with the following characteristics: i) Late blight and virus resistance; ii) Vigour to suppress weed growth; iii) Natural sprout suppression properties in storage; iv) Drought tolerance and v) Reduced reliance on expensive chemical inputs.

The objective of the study was to assess the potential for growing and storing Irish potatoes in northern Ghana.

II. METHODOLOGY

The feasibility study was executed between July and November, 2021. The study was implemented in a four-block replicated complete block design (RCBD) with three potato varieties (Mayan Rose, Maris Peer and Nadine) and replicated in three sites (‘Yapalsi’, Nebilyili and Wulensi) in Karaga, Gushegu and Nanuma South districts respectively. Besides variety and location as factors, planting method (on ridges and on flat land) was another factor. Below is the trial design (Table 1).

TABLE 1
TRIAL DESIGN

BLOCK A	MRR	MRF	MPR	NDF	MPF	NDR
BLOCK B	NDR	MRF	MPF	MPR	MRR	NDF
BLOCK C	MRR	MRF	MPF	NDF	MPR	NDR
BLOCK D	MPF	MRR	NDR	NDF	MRF	MPR

NB: MRR = Mayan Rose Ridged, MRF = Mayan Rose Flat, MPR = Maris Peer Ridged, MPF = Maris Peer Flat, NDR = Nadine Ridged and NDF = Nadine Flat

The RCBD is widely used in field experimentation and very appropriate when one is collecting quantitative data, such as yield, and requires a rigorous s comparison between treatments. The two cornerstones of the RCBD are *replication* (i.e., repetition) and *randomization.* These allow for the accommodation of any variability in the local environment and to determine the probability of the differences in results between treatments being real or simply due to chance (Gomez & Gomez, 1984). The main purpose of blocking is to reduce experimental error by eliminating sources of heterogeneity such as soil fertility or field slopes (CIP, 2006).

For this study, where three Irish potato varieties and two planting regimes were tried, one acre land with four replicate blocks was cultivated at each site. Each block contained six treatment plots with size of a plot being approximately 40m^2 (Table 1). The treatments are: Mayan Rose on ridge (MRR), Mayan Rose on flat land (MRF), Maris Peer on ridge (MPR), Maris Peer on flat land (MPF), Nadine on ridge (NDR) and Nadine on flat land (NDF). This brings the total of plots per trial site to 24. Each treatment appeared ones and randomly in every block.

2.1 Land Preparation:

Growing potatoes requires extensive soil preparation (Asia Farming, accessed on 20th Septemer, 2019). Therefore, in this trial, the land preparation was done at two levels of ploughing and ridging. The first ploughing was done to clear the land of all standing vegetation (grass, crop stubble and shrubs). In cases where there were still standing vegetation after the first ploughing, they were cleared manually. The second ploughing (harrowing) was done to roll the soil to produce the fine tilth that is required for growing of potato. After the second ploughing, ridges were made manually, on which the planting was done.

2.2 Planting:

Generally, seed requirement depends on the cultivar and soil type. In potato cultivation, seed required per hectare is 1,300 to 2000 kg (Asia Farming, accessed on 20th September 2019). In this trial, 1000 kg of each of the three potato varieties were planted across the three sites, implying approximately 333 kg of each variety per plot. Planting was done at a spacing of 60 cm (inter row) and 30 cm (intra row) and at a depth of 10 cm. Planting was done at a time that there is sufficient moisture in the soil (not wet) and the soil temperature is not above 22 ^{o}C. Planting was done on both ridges and on flat land to measure if there is any effect of ridging on the yield potential. The main issue encountered was the fact that the Maris Peer variety from arrival at the airport in Ghana to the time of planting suffered a lot of rotting. Samples of the rotten/dead plants were taken to the Laboratory for the isolation of the associated fungal species.

FIGURE 1: Planting

Maris Peer **Nadine** **Mayan Rose**

FIGURE 2: Potato seed on arrival from the UK

2.3 Fertilizer Application:

Before the fertilizer administration, soil analysis was conducted at each of the trial sites (Table 2) to determine the level of fertility of the soil, which in turn informed the NPK ratios to adopt. Fertilizer (NPK) application was done at planting at the rate of 300kg/ha, 550kg/ha and 200k/ha respectively for nitrogen, phosphorous and potassium. Aside the NPK, foliar-fertilizer (Croplift) was also applied at the rate of 2L/ha.

TABLE 2
RESULTS OF SOIL ANALYSIS

LAB NO	SAMPLE ID	pH (H2O 1:2:5)	% (O.C)	% N	P mg/Kg	K mg/Kg	Cmol+/kg (Ca)	Cmol+/kg (Mg)	Cmol+/kg (CEC)	TEXTURE		
										% SAND	% SILT	% CLAY
245/20	N1	6.51	1.014	0.1	8.11	71	4.8	3	9.62	59.92	30.32	9.76
246/20	N2	6.78	1.2285	0.12	9.48	76	4.6	2	8.55	63.92	28.32	7.76
247/20	N3	6.73	1.5405	0.15	12.36	79	4.6	3	9.63	65.92	26.32	7.76
248/20	N4	6.8	1.248	0.12	9.78	77	5.4	1.2	8.57	65.92	26.32	7.76
249/20	W1	6.86	1.1115	0.11	9.65	72	2.4	0.8	5.05	71.92	22.32	5.76
250/20	W2	6.86	1.1895	0.12	9.97	73	3.2	0.4	5.47	71.92	18.32	9.76
251/20	W3	6.65	1.1115	0.1	9.38	72	2.6	0.4	4.85	71.92	18.32	9.76
252/20	W4	6.64	1.3845	0.13	11.64	78	2.8	0.2	5	73.92	19.32	6.76
253/20	Y1	6.56	1.0725	0.11	9.77	69	3.4	0.4	5.57	73.92	20.16	5.92
254/20	Y2	6.53	0.7995	0.07	7.29	58	1.6	0.4	3.49	73.92	22.16	3.92
255/20	Y3	6.59	1.3065	0.13	10.67	76	5	2.2	9.15	75.92	20.16	3.92
256/20	Y4	6.42	0.819	0.08	8.96	67	3.4	3.4	8.52	75.92	20.16	3.92

2.4 Weeding:

Weeding is one of the important intercultural operations that was conducted throughout the trial, albeit manually. First weeding was carried out when the plants were about 20 cm high and the second weeding was carried out three weeks afterwards. Alongside the weeding operations, earthing up was carried out to keep the soil loose for proper development of tubers and for the protection of the developing tubers from direct contact with the sun, which could lead to greening of the tubers.

2.5 Pests/Disease Monitoring:

The potato like many other crops in the Solanaceae family, is susceptible to many pests and diseases (CIP, 2019, Hillary & Otieno, 2019, Okonya et al., 2016; Okeyo et al., 2019). The common pest of the potato include: Colorado potato beetle (*Leptinotarsa decemlineata*), Potato tuber moth (*Phthorimaea operculella),* Leafminer fly (*Liriomyza huidobrensis*) and Cyst nematodes (*Globodera pallida* and *G. rostochiensis*). The common diseases of potato include: Late blight, caused by *Phytophthora infestans,* Bacterial wilt and Potato blackleg (bacterial infection). Increasing potato production while protecting producers, consumers, and the environment requires an integrated approach encompassing a range of strategies: encouraging natural pest predators, breeding varieties with pest/disease resistance, planting clean seed, rotating with other crops, and organic composting to improve soil quality

Raising potato varieties that are pest/disease resistant is one of the ways to increase potato production while protecting producers, consumers and the environment (CIP, 219). Although, the potato varieties used in this trial are relatively resistant to diseases and pests, efforts were made to scout for potential pests and diseases that might attack the crop in the trial areas. This was to assist the project to come out with integrated and sustainable approaches to addressing pests and diseases in subsequent projects to scale up the production of Irish potato in Ghana.

FIGURE 3: Checking plants for symptoms of disease & Disease condition observed on the field

2.6 Fungal Isolation:

2.6.1 Media Preparation:

The Potato Dextrose Agar (PDA) (Oxoid, UK) was prepared by suspending 39 g of PDA powder in 1000 cm^3 of distilled water. To this 150 mg of amoxicillin was added to suppress bacteria growth and the mixture stirred on hot electric plate to dissolve the solutes. This was then autoclaved at 121 ºC at a pressure of 1.03 kg/cm^3 for 15 minutes. About 20 ml of the molten PDA was then poured into a 9 cm diameter Petri dish to solidify.

2.6.2 Isolation of fungi from root system of Irish potato crops:

The root of the Irish potato crop varieties was thoroughly washed with running tap water to remove soil particles and dead loose root tissues. Pieces (fragments of 0.5 cm long) of the root system were obtained. These were then surface sterilized with 70 % alcohol for 1 minute, and then washed in three changes of sterile distilled water. The fragments were then blotted dry with sterile tissue paper. The pieces were then inoculated on PDA in Petri dish and then incubated at room temperature (28 ± 2 ºC) for fungal growth. The mycelia that grew were sub cultured until pure cultures of the fungi isolate were obtained.

2.6.3 Isolation of fungi from healthy and rotten Irish potato tubers:

Both healthy and Irish potato tubers with rot symptoms were washed under running tap water to remove any debris on them. Pieces (0.5 cm^3 fragments) of tissues were obtained from the heathy Irish potato tubers. Also, pieces (0.5 cm^3 fragments) of tissues consisting of both rotten and healthy portions were obtained from the Irish potato tubers with rot symptoms. The pieces obtained from the heathy and rotten Irish potato tubers were each surface sterilized with 70% alcohol for 1 minute, washed with three changes of sterile distilled water and then blotted dry with sterile tissue paper. Five pieces of the tissues obtained from the healthy and rotten tubers were each inoculated separately at equidistance on PDA in a Petri dish. This was then incubated at room temperature for fungal growth. The grown fungi were sub cultured until pure cultures of each isolate obtained. Each treatment was replicated three times. The occurrence of the fungal isolates was determined with the formulae;

$$\% \text{ occurrence of fungi} = \frac{number\ of\ tissues\ infected\ by\ a\ fungus}{Total\ number\ of\ tissues\ plated} \times 100 \quad (1)$$

2.7 Identification of fungus isolate:

Slides of pure culture mycelia were observed under the microscope to determine its morphological characteristics. The fungus was then identified using its morphological and cultural characteristics as documented (Campbell 2013; Samson and Van Reenen-Hoekstra, 1988).

2.8 Pathogenicity test:

Healthy Irish potato varieties (Maris Peer, Mayan Rose and Nadine) were washed under running tap water and then surface sterilized with 70% alcohol. A 5 mm corkborer was used to remove a cylindrical core from the tuber to create a hole. A 5 mm disc of the test fungus mycelia was placed into the hole and the cylindrical core placed back. The wound was then sealed with Vaseline and the inoculated Irish potato tubers incubated under room temperature (28 ± 2ºC) for 14 days. The tubers were then cut transversely through the inoculated spot and examined for rot symptoms.

2.9 Harvesting and Storage:

The potato varieties used come to maturity and ready for harvesting after 3 months of sowing. The crop becomes ready for harvesting when leaves turn into yellow colour and there is easy separation of the tubers from their stolons (CIP, 2019). When these signs were observed, harvesting was done manually by the use of hoes. During harvesting, care was taken so as not to cause injury to the tubers. After harvesting, the potato tubers were weighed, labeled and stored in well protected storage environment, under airy and cool conditions to prevent sprouting.

III. DATA COLLECTION AND ANALYSIS

3.1 Evaluation parameters:

Once the trials have been established, the following data were collected during the growing season in accordance with established procedures by the International Potato Centre (CIP, 2006):

- Number of plants per plot: this data will be collected 45 days after planting
- Plant habit: this data was collected 45 days after planting
- Plant vigor: this data was collected 45 days after planting
- Flowering stage: this data will be collected 60 days after planting
- Senescence stage: this data will be collected 90 days after planting
- Disease and pest damage
- Number/weight/size tubers per plot
- Internal defects at harvest
- Tuber quality in storage
- Climate data.

Plant habit and flowering and senescence stages were measured using scales described by Gomez (2006) while Plant vigor was evaluated using a scale from 1 to 9 where "1" is assigned to least vigorous plants and "9" describes very vigorous plants.

Scouting was done during the growing period to record pest and disease incidences. This was done by just counting pest and disease incidences recorded by treatment plots.

At harvest, the tubers were graded into 3 categories and the weights and numbers of tubers in each category were recorded. The categorization was done according to CIP (2006) as follows:

>45 and <45

- Category I: commercial, tubers weighing 200-300 g or measuring >60 mm
- Category II: commercial, tubers weighing 80-200 g or measuring 30-60 mm and
- Category III: non-commercial, tubers weighing < 80 g or measuring < 30 mm

Reporting internal defects at harvesting is critical for estimating processing quality. In this regard, a sample of 10 commercial tubers was cut transversally and checked for external defects such as cracking, secondary growth and warts, and internal problems such as hollow heart, black spots, heat necrosis, and rot (CIP, 2006). For each entry, the number of affected tubers was recorded on the tuber yield datasheet and the percentage of affected tubers was calculated.

3.2 Data Analysis:

Since the trial design is RCBD in a Multi-locational variety trials (MLVT) data collected from the trial was analyzed using combined Analysis of Variance (ANOVA). This was done after testing the homogeneity of experimental variance across the sites, where experiments with high coefficients of variation will be eliminated from the analysis. The sources of variability used in the statistical model are the site, the blocks within each site, the treatment (variety and planting method), the site-treatment interaction and the experimental error.

IV. RESULTS

Data collected over the study period included temperature, germination and plant habit (plant height and vigour). The average temperature in area over the period was 22ºC min and 28ºC max.

With regards to germination, the final data was collected at 45 days after planting and the germination calculated thereof. The germination percentage for the various treatments are shown in figures 4, 5, and 6 for Nebilyili, Yapalsi and Wulensi respectively. Considering the fact that the Irish potato plant is suited for temperate conditions, it can be said that the germination in these experiments was good, as we recorded a germination between 0 and 99% for the Nebilyili, 1 and 85% for Yapalsi and between 0 and 100% for Wulensi. Germination percentage of 0 and 1 as recorded in this trial on the surface may appear bad compared to T1 (Wumbei et al., 2020, unpublished) which had the lowest germination percentage around 35, but this could be attributed to a number of factors such as; varietal difference, number of seeds planted per treatment and the age of the seed planted. In terms of varietal performance, the Mayan Rose variety recorded better germination than Maris Peer and Nadine. The Nadine variety performed worst as far germination was concerned.

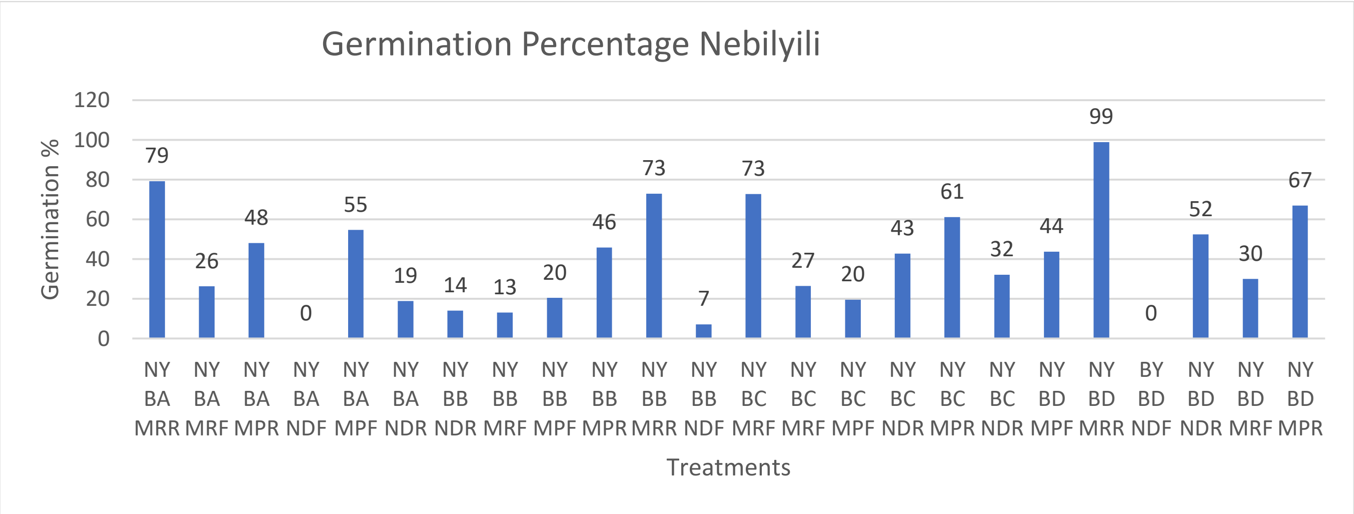

FIGURE 4: Germination Percentage at Nebilyili

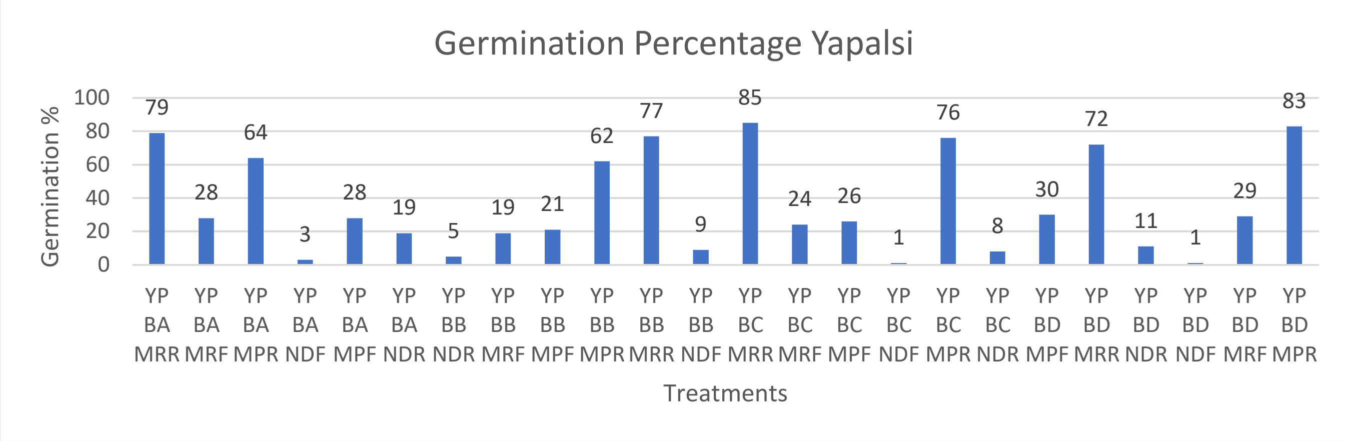

FIGURE 5: Germination Percentage at Yapalsi

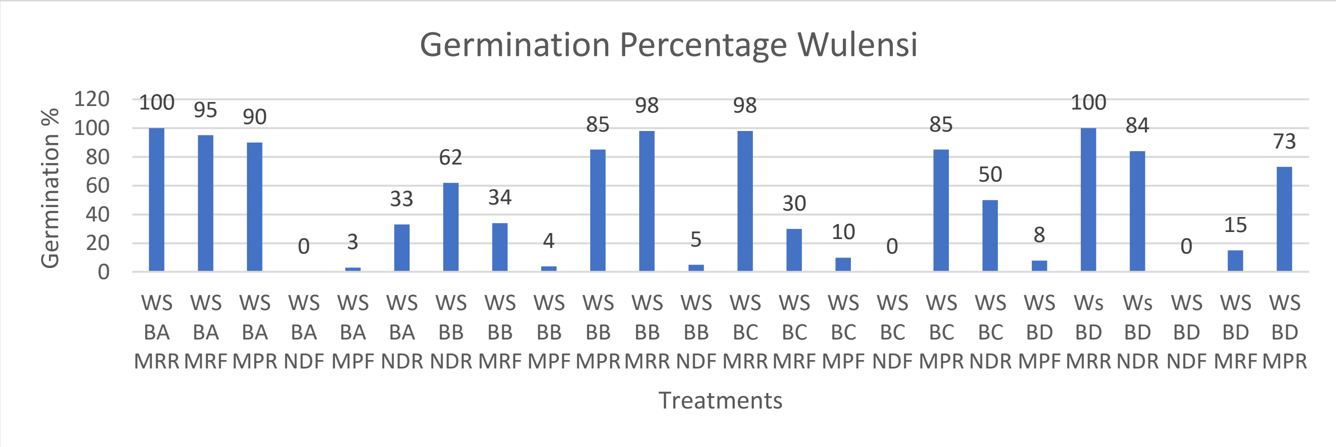

FIGURE 6: Germination Percentage at Wulensi

With regards to plant habit, the plants are looking vigourous compared to T1 which suffered a total die off at some point. Similar to the case of T1, the plants suffered some disease symptoms at 3wap and 6wap leading to the rotting of some of them, but the rotting was on a smaller scale compared to T1. The plant height from which the growth rate and the vigour were calculated was taken twice with one-week interval between the two measurements. In figure 7, 8 and 9 can be seen the plant growth rate for Nebilyili, Yapalsi and Wulensi respectively. The growth rate of the plants was not uniform among the varieties and across the sites. At the Nebilyili site, while BA MPR recorded a growth rate of almost 4, BB MRR recorded a negative growth rate of -2. Among the varieties, Maris Peer recorded the highest growth rate followed by Nadine and Mayan Rose respectively. The growth rate at the Yapalsi site, similar to the Nebilyili site was not also uniform and Maris Peer recorded the highest growth rate, but this time around followed by Mayan Rose with Nadine recording the lowest growth rate of -1.2. The growth rate at the Wulensi site was relatively uniform between 0.9 and 3.1 with Mayan Rose planted on flat land in block A recording the highest growth rate and Mayan Rose planted on ridges in block D recording the lowest growth rate.

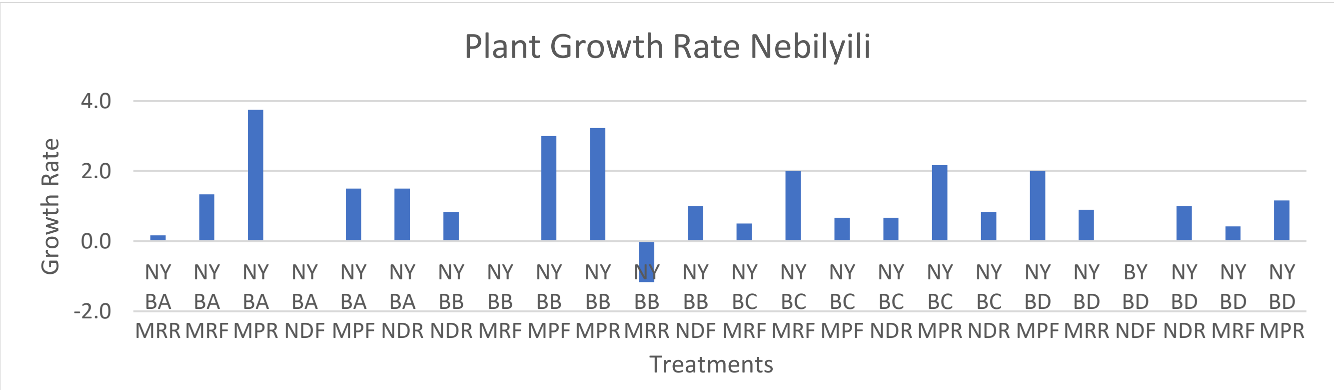

FIGURE 7: Plant Growth Rate at Nebilyili

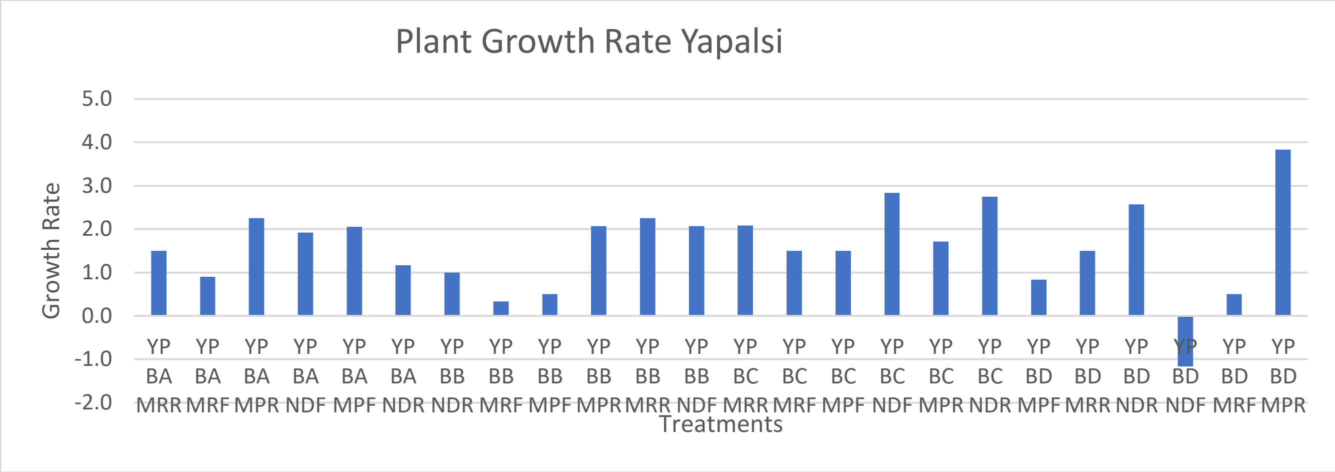

FIGURE 8: Plant Growth Rate at Yapalsi

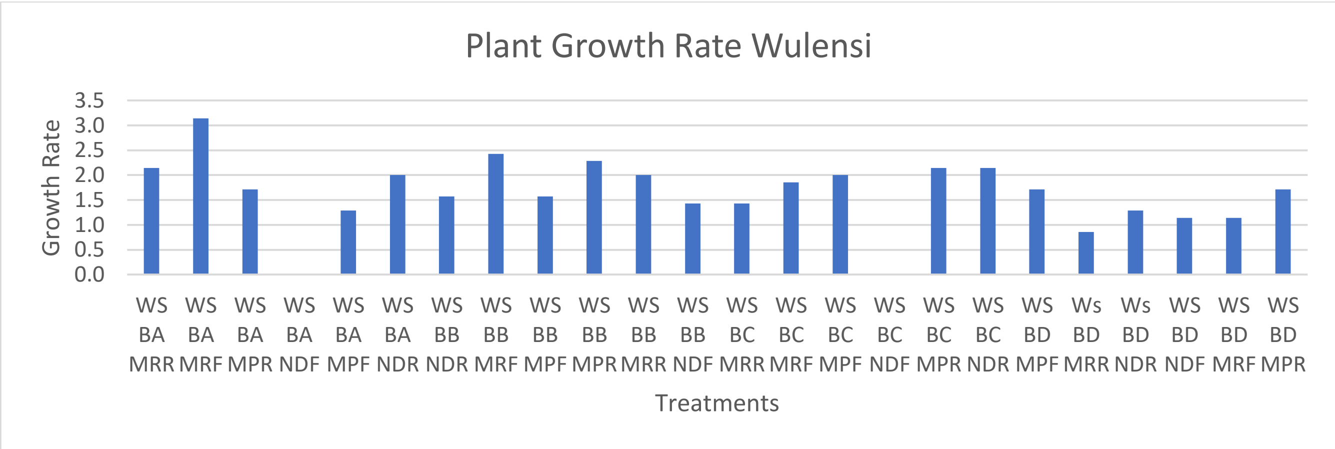

FIGURE 9: Plant Growth Rate at Wulensi

With regards to plant vigour, as stated earlier, this was calculated from plant height data picked at two times, with a week difference between the first and the second measurements. Vigour was calculated using the following formular: VI = S x (Gt/Dt), where S = Plant height, Gt = number of plants germinated in a treatment at the time of taking plant height, and Dt = number of days from first plant height measurement to the time of the second plant height measurement. The results are shown in figures 10, 11 and 12 for Nebilyili, Yapalsi and Wulensi respectively. On a scale of 1 to 10, where 1 is less vigorous and 10 is highly vigorous, the plants at the Wulensi site were observed to be more vigorous compared to those at Yapalsi and Nebilyili, since about 11 out the 24 treatments recorded moderate to high vigour while only 10 and 5 out of the 24 treatments, respectively in Yapalsi and Nebilyili recorded moderate to high vigour. In terms of varietal performance, Mayan rose appeared to be more vigorous than Maris Peer and Nadine.

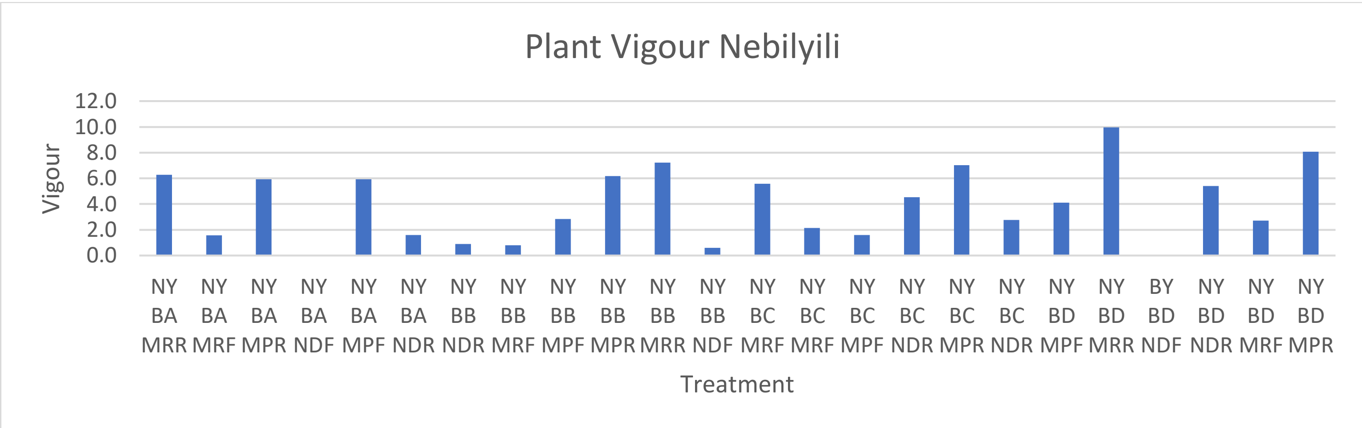

FIGURE 10: Plant Vigour at Nebilyil

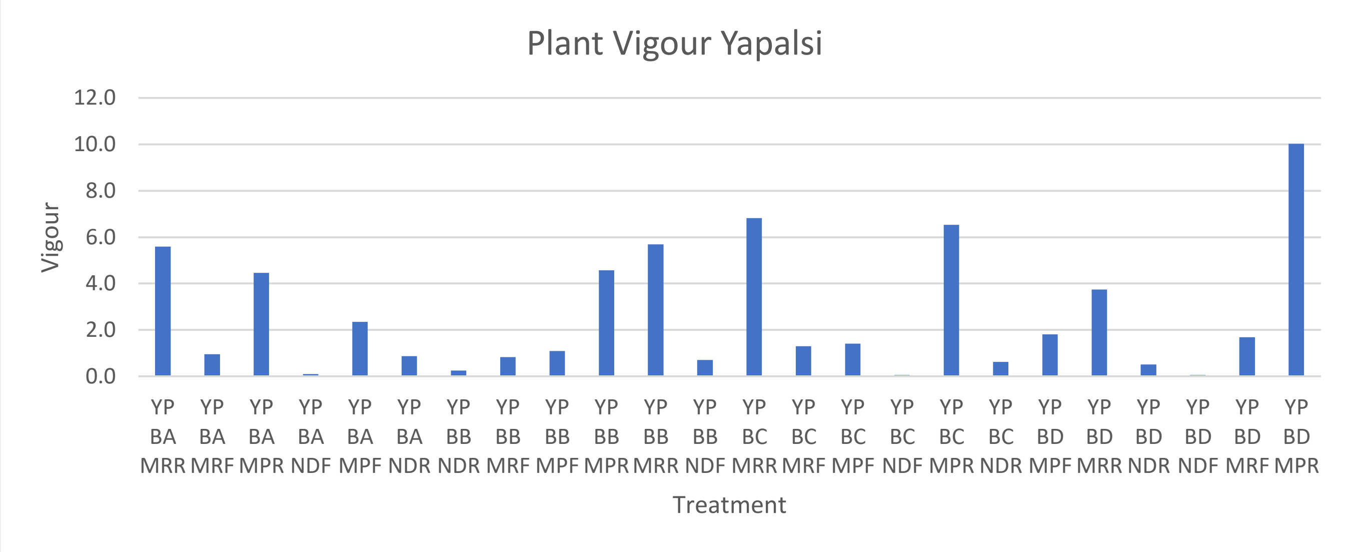

FIGURE 11: Plant Vigour at Yapalsi

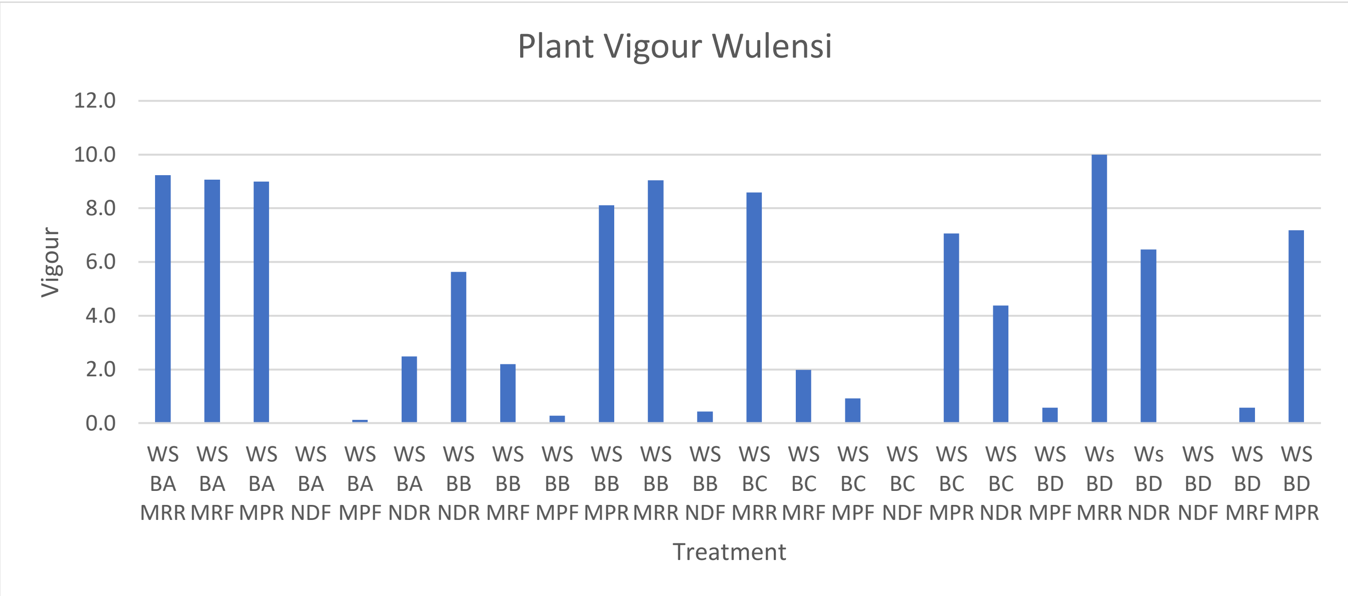

FIGURE 12: Plant Vigour at Wulensi

The crops were supposed to be monitored to the point of harvesting, where data on yield will be computed. Since the potato plants did not grow to full maturity (between 3 and 4 months) as a result a disease condition that set in, the yield was disappointingly low. As can be seen in figures 13, 14, and 15, generally, the yield was very poor, with a maximum of 3.1MT/ha compared to average local potato yield of 8MT/ha in Mozambique and as high as 50MT/ha in Europe and America (Belanger et al., 2000, Statista.com, accessed on 19th July, 2023). Among the varieties, Nadine performed better than the other two varieties (Mayan Rose and Maris Peer), although there was no significant difference ($P > 0.05$) between varieties. Among the three sites that were used for the trial, there was significant difference ($P < 0.05$) between Wulensi and the two other sites. The Wulensi site had improved yields over Nebilyili and Yapalsi. However, there was no significant difference between Nebilyili and Yapalsi. The potato seed were planted on both ridges and on flat land, but at harvest it was revealed that there was no significant difference ($P > 0.05$) between potato planted on ridges and those planted on flat land, even though, those planted on ridges produced more tubers than those on flat land. This difference can only be attributed to chance and a random occurrence.

At the Nebilyili site, out of the 24 plots planted, only 4 plots yielded crop. All of these four plots were of the Nadine variety and planted on ridges.

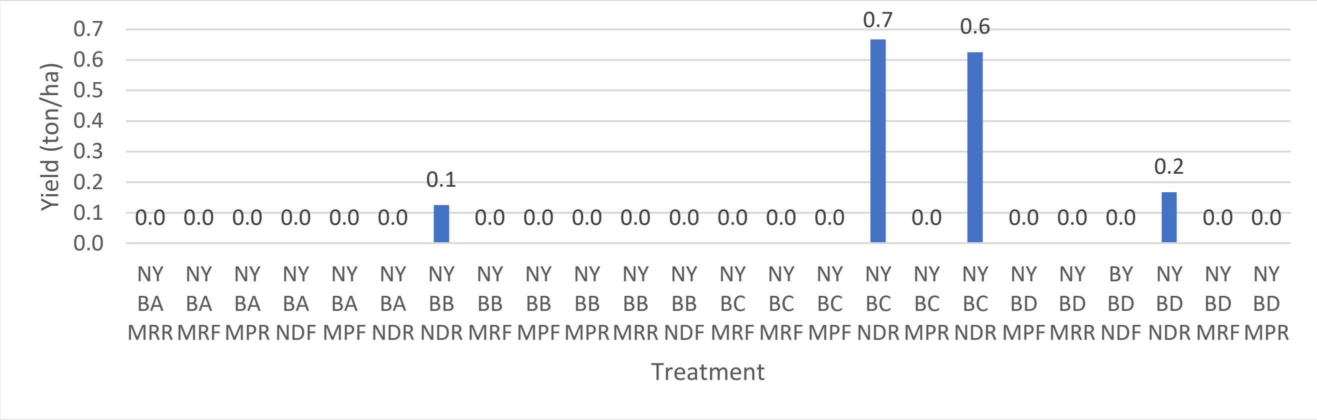

FIGURE 13: Yield (ton/ha) at Nebilyili

At the Yapalsi site, out of the 24 plots planted, only one plot produced some yield and that was also the Nadine variety planted on ridges similar to the Nebilyili site.

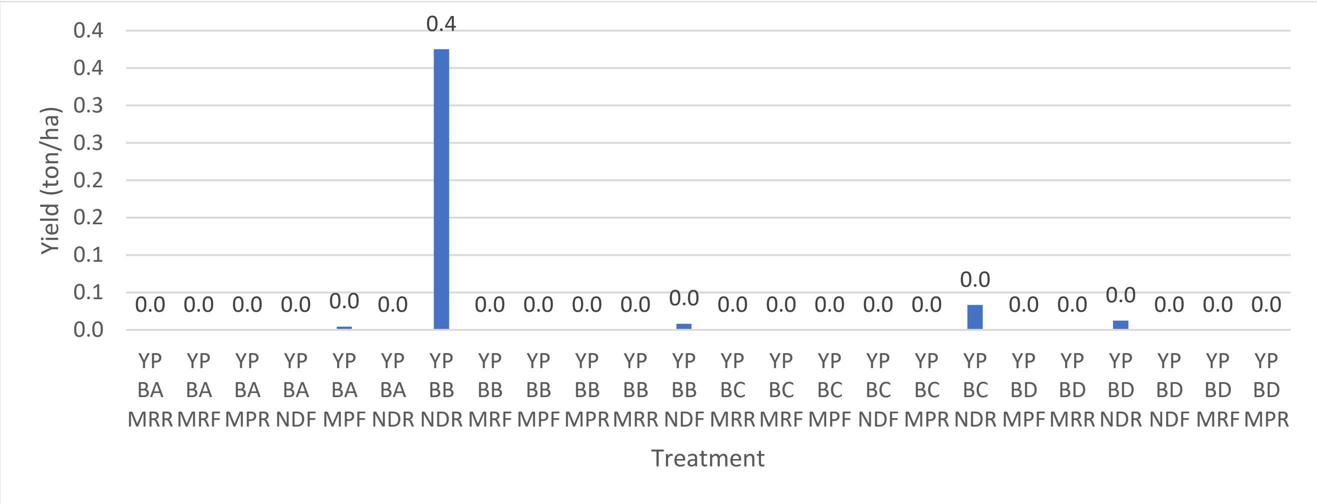

FIGURE 14: Yield (ton/ha) at Yapalsi

In contrast, to the Nebilyili and Yapalsi results, at the Wulensi site, out of the 24 plots planted, a total of 14 plots produced some yield. Out of the 14 plots from which yield was obtained, 5 were planted of the Nadine variety, 5 Mayan Rose and 4 Maris Peer. Of the 14 plots with yield, 12 were planted on ridges whilst 2 were on flat land. The ridged planting resulted in the higher yields.

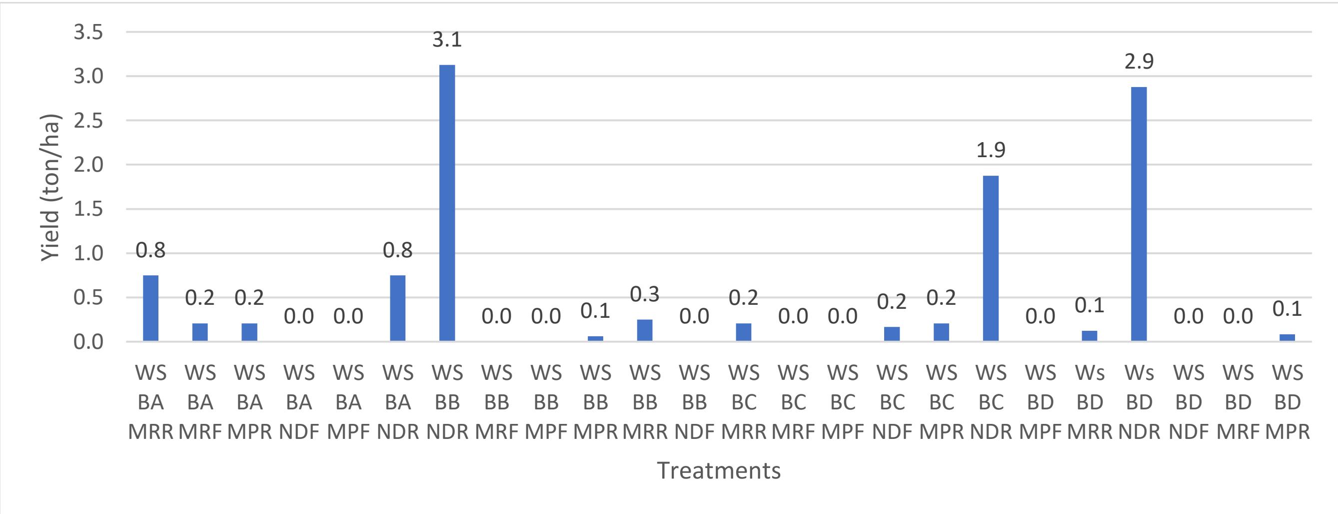

FIGURE 15: Yield (ton/ha) at Wulensi

4.1 Fungi isolates from healthy and rotten Irish potato tubers:

The fungal species *A. flavus, A. fumigatus, A.oryzae* and *F. oxysporum* were isolated from the healthy Irish potato tubers (Figure 16). *Aspergillus flavus* and *F. oxysporum* were recorded for Mayan Rose, Nadine and Maris Peer varieties of the Irish potato. *A. fumigatus* was only recorded for Mayan Rose, while Maris Peer only recorded occurrence for *A. oryzae*.

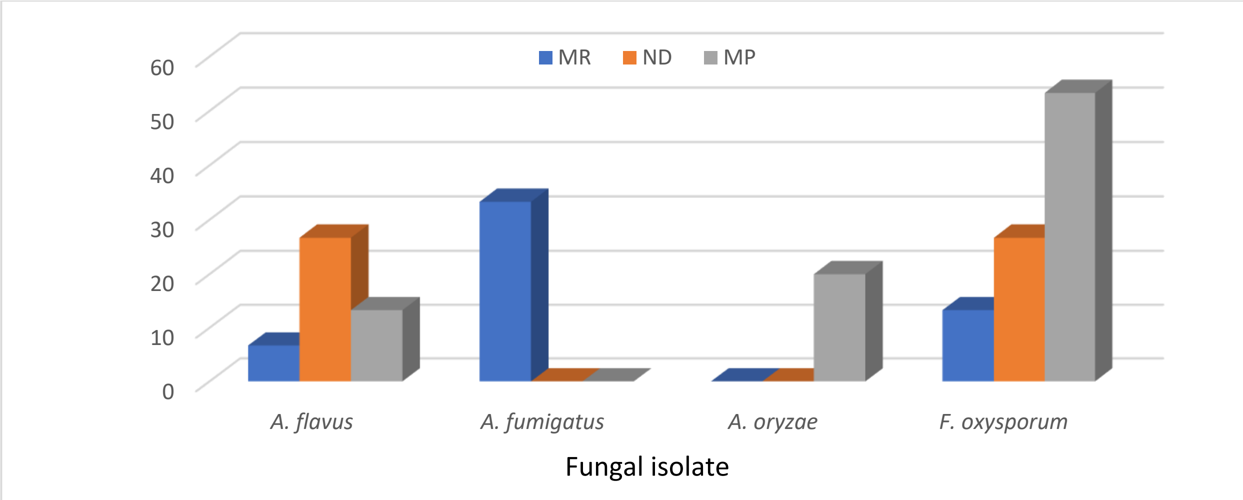

FIGURE 16: Fungal species isolated from healthy tubers of Mayan Rose, Nadine and Maris Peer varieties of the Irish potato

The fungal species recorded for the rotten Mayan Rose, Nadine and Maris Peer varieties of the Irish potato were *A. flavus, A. fumigatus, A. oryzae, A. tamaarii, F. oxysporum* and *Penicillium brvicompactum* (Figure 17). *Aspergillus flavus* and *F. oxysporum* were recorded for all the rotten tubers of the three varieties of the Irish potato varieties (Mayan Rose, Nadine and Maris Peer). *Aspergillus fumigatus* was recorded for Mayan Rose and Maris Peer but not Nadine. Only Nadine recorded occurrence for *A. oryzae*. Also, *P. brevicompactum* was only recorded for Mayan Rose.

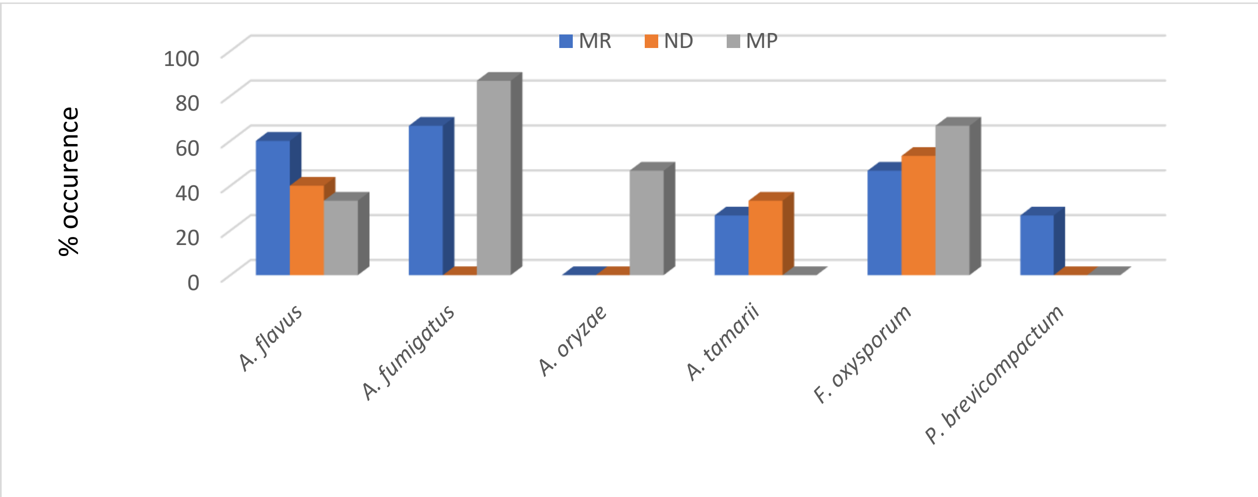

FIGURE 17: Fungal species isolated from rotten tubers of Mayan Rose, Nadine and Maris Peer varieties of the Irish potato

The pathogenicity test confirmed *A. flavus, A. fumigatus, A. oryzae, A. tamaarii, F. oxysporum* and *P. brvicompactum* as Irish potato tuber rot fungal pathogens. This agrees with the findings of Ibrahim et al. (2014) and Gashgari and Gherbawy (2013).

The fungi *A. flavus, A. fumigatus, A. oryzae* and *F. oxysporum* which were isolated from both the healthy and rotten Irish potato tubers could have been on the healthy potato tubers as normal mycoflora which became opportunistic pathogens under favourable environmental conditions for infection. Also *A. flavus, A. fumigatus, A. oryzae* and *F. oxysporum* could have induced a latent infection on the healthy Irish potato tubers which expressed rot symptoms as time progressed.

TABLE 5
FUNGI ISOLATED FROM IRISH POTATO PLANTS (ROOT SYSTEM)

No.	Code	Fungi							
		Fusarium oxysporum	*Penicillium citrinum*	*Alternaria alternata*	*Aspergillus flavus*	*Aspergillus niger*	*Aspergillus ochraceus*	*Trichoderma harzianum*	*Mucor hiemalis*
1	NY BAMRR	+	+	-	-	-	-	-	-
2	NY BAMRF	+	+	-	-	-	-	-	-
3	NY BAMPR	+	+	-	-	-	-	-	-
4	NY BA NDF	+	+	-	-	-	-	-	+
5	NY BA MPF	+	+	-	-	-	-	-	-
6	NY BB NDR	+	+	-	-	-	-	-	+
7	NY BB MRF	+	+	-	-	-	-	-	-
8	NY BB MPF	+	+	-	-	-	-	-	-
9	NY BB MPR	+	+	+	-	-	-	-	-
10	NY BB NDR	+	+	-	-	-	-	-	-
11	NY BC MRF	+	+	-	-	-	-	-	-
12	NY BC NDF	+	+	-	-	-	-	-	-
13	NY BC MPF	+	+	-	-	-	-	-	-
14	NY BC NDR	+	+	+	-	-	-	-	-
15	NY BC MPR	+	+	-	-	-	-	-	+
16	NY BDMPR	+	+	+	-	-	-	-	-
17	NY BDMRR	+	+	+	-	-	-	-	-
18	NY BD NDF	+	+	+	-	+	-	-	-
19	NY BDNDR	+	+	-	+	-	-	-	-
20	NY BD MPF	+	+	+	-	-	-	-	-
21	YP BA NDR	+	+	+	-	-	-	-	+
22	YP BA MPF	+	+	+	+	-	-	-	-
23	YP BA MPR	+	+	+	-	-	-	-	-
24	YP BA NDF	+	+	-	-	-	-	-	-
25	**YP BB NDR**	**+**	**+**	**+**	**-**	**-**	**-**	**-**	**-**
26	YP BB MRF	+	+	-	-	-	-	+	-
27	YP BB MPF	+	+	-	-	-	-	+	-
28	YP BB MPR	+	+	-	-	-	-	-	-
29	YP BC MRR	+	+	-	-	-	-	-	-
30	YP BC MRF	+	+	-	-	-	-	-	-
31	YP BC MPF	+	+	-	-	-	-	-	-
32	YP BC NDF	+	+	-	-	-	-	-	-
33	YP BD MPF	+	+	+	-	-	-	-	-
34	YP BD MPR	+	+	+	-	-	-	-	-
35	YP BD NDR	+	+	-	-	-	-	-	+
36	YP BD NDF	+	+	-	-	-	-	-	+
37	YP BD MRF	+	+	-	-	+	-	-	+
38	WS BA NDF	+	+	-	-	-	-	-	+
39	WS BA MPF	+	+	-	-	-	-	-	+
40	WS BA MPR	+	+	+	-	+	-	-	-
41	WS BB NDR	+	+	-	-	-	-	-	+
42	WS BB MRF	+	+	-	-	-	-	-	-
43	WS BB MPF	+	+	-	-	-	-	-	-
44	WS BC NDF	+	+	-	-	-	-	-	-
45	WS BC MRF	+	+	-	-	-	-	-	+
46	WS BC MPF	+	+	-	-	-	-	-	+
47	WS BD MPF	+	+	+	-	-	-	-	-
48	WS BD MPR	+	+	+	-	-	-	-	-

Key: *+ = fungi present; - = fungi absent = fungi absent, NY= Nebilyili, YP = Yapalsi, WS = Wulensi, BA = Block A, BB = Block B, BC = Block C, BD = Block D, MP = Maris Peer, MR = Mayan Rose, ND = Nadine, R = Ridge and F = Fatland*

The fungal species isolated from the root system of the Mayan Rose, Nadine and Maris Peer Irish potato varieties obtained from the fields of Nebilyili, Yapalsi and Wulensi were *Alternaria alternata, Aspergillus flavus A. niger, A. ochraceus, Fusarium oxysporum, Mucor hiemalis, Penicillium citrinum* and *Trichoderma harzianu* (Table 3). Although *Fusarium oxysporum* and *P. citrinum* were recorded among all the root systems examined, *Alternaria alternata, Aspergillus flavus A. niger, A. ochraceus, Mucor hiemalis* and *Trichoderma harzianum* were not recorded among all the root system examined. Among the various fungi isolated from the root system of the Irish potato crops, *F. oxysporum* is pathogenic to the Irish potato and causes Fusarium wilt in the crops. Symptoms of Fusarium wilt was expressed among some of the Mayan Rose, Nadine and Maris Peer varieties of Irish potato cultivated at the Nebilyili, Yapalsi and Wulensi locations; resulting in poor crop establishment on the field.

V. CONCLUSION AND RECOMMENDATION

Based of the study findings presented above, it can be concluded that there is the potential for Irish potato to be grown as another food crop in Ghana.

It is recommended that further studies should be conducted under irrigation, rain fed and green house conditions to determine the best conditions under which optimum yields can be obtained to feed the teaming Ghanaian consumers of the Irish potato.

ACKNOWLEDGEMENT

We wish to acknowledge the support of Ms. Lisa Mynheer, Director Luminno for contributing to securing the grant for the project and serving as the Project Administrator. We wish to also acknowledge the support of Mr. Alhassan Tampuri, the commercial farmer, for providing the land and mobilizing other farmers for the implementation of the project. Special mention has to be made of the support of Mr. Abdul Rahamani Shahadu of Wulensi, Alhaji Fusheini of Nebilgbini and Abdalla of Yapala for taking good care of our farms in their respective communities.

The project was sponsored by Innovate UK under the AgriTech Catalyst Round 7 funding (Project No. 105315).

REFERENCES

[1] Adepoju, O. T., Bamigboye, A. Y., and Okafor, A. C. (2010). Proximate and mineral composition of whole and dehulled Nigerian sesame seed. *African Journal of Food Science and Technology* (ISSN: 2141-5455) Vol. 1(3) pp. 071-075, September, 2010.

[2] AsiaFarmig (2019). Potato Cultivation Information Guide. https://www.asiafarming.com/potato-cultivation, accessed on 20th September, 2019.

[3] Be1anger G., Walsh, J. R., Richards J. E., Milburn P. H., and Ziadi N. (2000). Yield Response of Two Potato Culivars to Supplemental Irrigation and N Fertilization in New Brunswick. *Amer J of Potato Res (2000) 77:11-21.*

[4] Campbell, C. K., & Johnson, E. M., Warnock D. W (2013). *Identification of pathogenic fungi*. 2nd edn. John Wiley & Sons.

[5] Darfour, B. and Rosentrater K. A. (2016). Agriculture and Food Security in Ghana. *An ASABE Meeting Presentation* DOI: 10.13031/aim.20162460507 Paper Number: 162460507.

[6] Esmniger, A. H. and Esminger M. E. (1994). Food and Nutrition encyclopedia Essien AI., Ebana RUB, Udo HB (1992). Chemical evaluation of pod and pulp of the fluted FAO (2009). Guidelines for sustainable potato production.

[7] Gashgari, R. M., & Gherbawy, Y. A. (2013). Pathogenicity of some Fusarium species associated with superficial blemishes of potato tubers. *Polish Journal of Microbiology, 62*(1), 59-66.

[8] Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedures for Agricultural Projects.

[9] Hillary, M. Otieno O. (2019). Impacts and Management Strategies of Common Potato (Solanum tuberosum L.) Pests and Diseases in East Africa. DOI: 10.5923/j.fs.20190902.01.

[10] Ibrahim, M., Shehu, K., Sambo, S., Tukur, U., Umar, I. A., & Tafinta, I. Y. (2014). Identification of fungi associated with storage rots of Irish Potato (Solanum Tuberosum l.) tubers in Sokoto Metropolis. *Annals of Biological Sciences*, *2*(2), 1-4.

[11] International Potato Center (CIP), (2006). Procedures for standard evaluation trials of advanced potato clones. An International Cooperators' Guide.

[12] International Potato Centre (CIP), (2020). The Potato Crop: Its Agricultural, Nutritional and Social Contribution to Humankind. ISBN 978-3-030-28682-8 ISBN 978-3-030-28683-5 (eBook) https://doi.org/10.1007/978-3-030-28683-5.

[13] Johnson, C. M., and Cheein, F. A. (2023). Machinery for potato harvesting: a state-of-the-art review. *Front Plant Sci.* 2023; 14: 1156734.

[14] Okeyo, G. O., Narla, R. D., Otieno, H. M. O., & Schulte-Geldermann, E. (2019). Response of Selected Potato Genotypes to Natural Virus Infection in the Field. Asian Journal of Research in Crop Science, 1-13.

[15] Okonya, J. S., & Kroschel, J. (2016). Farmers' knowledge and perceptions of potato pests and their management in Uganda. Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS), 117(1), 87-97.

[16] Ortiz, O. and Mares, V. (2017). The Historical, Social, and Economic Importance of the Potato Crop. *The Potato Genome* pp 1–10.

[17] Samson R A, Van Reenen-Hoekstra E S (1988). *Introduction to food-borne fungi*. Baarn, Delft, The Netherlands: Centraalbureau voor Schimmelcultures.

[18] Spooner, D. M., Ghislain, M., Simon R., Jansky S. H. and Gavrilenko T. (2014). Systematics, diversity, genetics, and evolution of wild and cultivated potatoes. *Bot Rev* 80:283–383.

[19] Statista (2023). Average potato production per hectare in the Netherlands from 2012 to 2021. Accessed 19th July, 2023 via https://www.statista.com/statistics/753103/average-potato-production-per-hectare-in-the-netherlands/.