Evaluation of Sweet Potato (*Ipomoea batatas*) for early blast disease (*Alternaria solani*).

Abstract

Aims:Early blight disease (*Alternaria solani*) is one of the main biotic factors limiting sweet potato production in the tropics. A multi-locational research was carried out to screen and identified sweet potato accessions that are resistant to the disease.**Methodology**: 21 sweet potato accessions were collected from different agro-ecological zones of Nigeria and screen against *Alternaria solani* by artificial inoculation of the pathogen in three diverse agro-ecological conditions. The accessions were named against their place of condition.The research were laid out in a Randomized Complete Block Design (RCBD) with three replications.Data were collected on days to 50% flowering, fresh root weight per plant, number of root per plant, number of main branches per plant, and above ground fresh biomass yield per plant at 15 weeks after planting (WAP).Disease scoring was done using rating scale 0f of 0-9 and analyzed with IRRI STAR software.**Results:**The result revealed that there are variations in the 21 accessions studied. Offa performed best across the three environments followed by Umudike while Ado-Ekiti had the least performance in term of root yield.The screening shows that none of the 21 accessions is highly resistant. Four of the accessions wereresistant, six accessions were moderately resistant, four accessions were susceptible, and three accessions were moderately susceptible while 4 accessions were highly susceptible to the pathogen.**Conclusion:**Thefindings concluded that the resistant accessions that gave high number roots could be used as a gene pool for *Alternaria solani*resistance breeding for cultivar improvement. The use of the identified resistant accessions with high root yield by farmers is encouragedpending the time commercial *Alternaria solani*resistant cultivars will be readily available and accessible.

Keywords: *Alternaria solani*, Improvement, Nigeria, Resistant, Susceptible, Sweet potato.

Introduction.

Ipomoea batatas(L.) Lam popularly called Sweet potato in English Language is one of the most valued food crop globally. The crop produce tuberous roots that serve as food for humans, feed for livestock and used as industrial raw material for various industries [1]. The utilization of the plant's roots and leaves has helped in securing food security and assist in reducing health challenges that arose due to high level of malnutrition particularly in children and pregnant women [2-3]. According to [4], there are more than 400 sweet potato species with different flesh and skin colour.The average composition of sweet potato flesh has43.5% total starch, 2% protein, 0.4% lipids, 4.4% ash, and 49.7% total dietary fiber [5]. Orange flesh sweet potato is very rich in bioactive compounds such as phenolic acids and carotenoids [6].Researches had reported the beneficial effects of sweet potato on human and animal metabolisms,such as anti-inflammatory, anticancer, antidiabetic effect [7-9].

Various biotic and abiotic factors affect the crop production globally especially where modern farming techniques is adopted. Poor or improper harvesting, storage and transportation methods also affect crop quality [10]. Moreover, the Sweet potato is not exempted from other crops that the mentioned factors affect. Early blight is a major biotic factor affecting sweet potato production on the field. The disease attacked the plant foliage and vines [11]. Early blight disease is caused by *Alternaria solani*. The disease could cause significant roots and leaves yield reduction which will invariably lead to poor farmers' income or total loss of investment. Roots losses due to early blight disease ranges between 50-90% [12] and 100% in severe outbreak [13]. The effects of early blight slow down photosynthetic rate in the plant [14]. The disease continue as rot on the roots in storage resulting to root spoilage and degradation of essential nutrients in the plant edible roots [15].

Several management approaches have been developed to manage early blight disease of sweet potato including farm hygiene, and any of these approaches or its combination were adopted the growers based on the resources available at his or her disposal or based on technical know-how. Amongst the management approaches include the use chemicals, biological and cultural approaches, and the use of resistant varieties. The use of chemicals seems to be more effective in managing the disease, thus the approach has been the most widely used. The chemicals are detrimental to human and livestock health and the environment at large. Moreover, it is expensive thus increase the cost of production.

The outcry of environmental conservative scientists have called for the development of pests and diseases control measures that will not tamper with the environment. Growing of crop cultivars that are diseases resistant, adopting excellent agronomic practices and proper nutritional management or integration of any of these methods are good measures in controlling the diseases without hampering the environment [16]. The development of cultivars that are resistance to early blight will serve as the most suitable approach for farmers as it does not required any additional resources to procure orneed a special skill to adopt. However, the need to screen and identified cultivars with genes that resistant to the blast disease amongst the local germplasm becomes paramount [17].

This research aimed at screeningSweet potato accessions and identify the accession(s) that are resistant to early blast disease (*Alternaria solani*) in agro-ecological zones in southern Nigeria to be recommended for farmers to cultivate and used for further breeding work for crop improvement

MATERIALS AND METHODS

The study locations

The research was conducted at the Biotechnology Laboratory, Elizade University, Ilara-Mokin, Nigeria, and three field environments; Ekiti State University Teaching and Research Farm, Ado-Ekiti, University of Medical Sciences Biological Gardern, Ondo-City and Oke-Ako/Irele Farm Settlement, Oke-Ako Ekiti Nigeria. Ondo City and Oke Ako-Ekiti is located in Evergreen forest and derived guinea savanna agro-ecological zone of Nigeria respectively while Ado-Ekiti is located in the vegetation that is intermediate between the forest and savannah zone. The three experimental locations have two distinct seasons. (Rain and dry).

Experimental materials

The experimental materials used for this work comprised 21 sweet potato accessions collected from different agro-ecological zones of Nigeriato ensure genetic diversity. The collected sweet potato vines were properly sterilized to get rid any form of pathogen(s) probably if there is any.

Isolation, purification of the *Alternaria solani*inoculum and its pathogenicity test

Diseased sweet potato (petioles and vines) with typical symptoms of early blight was obtained from endemic sweet potato farm in Ado-Ekiti, Ekiti State.The diseased plant parts (petioles and vines) were taken to the Biotechnology Laboratory, Elizade University, Ilara Mokin Nigeria for the pathogen isolation, characterization and purification according to [18].The pathogenicity of the isolates were established according to Koch's postulates. The agar slants with the Petri dishes containing *Alternaria solani*inoculum were stored at 5^0C [19].

Soil sampling and analysis

12 soil samples were randomly obtained at the depth of about 0-30 cm from each of the experimental field to form one composite sample before land preparation in all the experimental locations. The soil samples were collected with sterilized soil auger and packed into a sterilized enveloped and well labelled. The composite soils were well air-dried, grinded, and sieved using a 2 mm sieve. The composite soil samples were analyzed for the determination of the selected physio-chemical properties of the soil.

Field experimental design and cultivation condition

The research was laid out in a Randomized Complete Block Design (RCBD) with three replicates across the three environments. The vegetation were manually sliced with cutlasses and packed.Ridges were made with hoes. A spacing of 1 m x 1 m was adopted. The vine planted comprises of 4-5 nodes for all the accessions.Good agronomics practices were adopted to ensure excellent crop performance.

Inoculum preparation and inoculation

The isolated, characterized and purified *Alternariasolani* inoculum preserved at 5^0C was re-cultured for multiplication in Potato Dextrose Agar (PDA) medium. The preparation of conidial suspension, adjustment of final inoculum concentration for good sporulation stimulationand proper inoculation was carried out using [10] procedure. Tween 20 was applied to the gelatin (0.02% Tween 20 in 0.25% gelatin) to the prepared suspension to enhance a good adherence of conidia to the sweet potato aerial parts [20].

At six weeks after planting (WAP), the plants were uniformly inoculated at 18:00 hour of the day with suspension of the characterized pathogen (1 x 10^5 spores/ml of distilled water) containing 0.02% Tween 20 in 0.25% gelatin per plot using a knapsack sprayer to run-off. After inoculation, the fields were sprayed with water at 8:00 hour of the day the next morning. Watering continues with knapsack sprayer on the plants six times at two hours intervals after 15 hours of inoculation.

Disease assessmentanddata collection

Data were taken on the number of sweet potato plants that came down with *Alternaria solani*per replicate at 15 WAP across the three environments.The severity of the diseasewas determined based on the formula adopted by [15]. Percentage incidencewas determined using [21]. Data were collected at Days to 50% flowering, fresh root weight per plant, number of roots per plant, number of main branches per plant, and above ground fresh biomass yield per plant at15 WAP. The data collected were analyzed using IRRI STAR software [22]. Means were separated by Duncan's multiple range test (DMRT) (P = 0.05).

Table 1:**List of sweet potato accessions showing their source of collection**

S/N	Location	Agro ecological zone	S/N	Location	Agro ecological zone
1	Sokoto	NGS	12	Kano	NGS
2	Ilorin	SGS	13	Iresi	FZ
3	Mokwa	SGS	14	Ondo-city	FZ
4	Kujama	NGS	15	Abeokuta	FZ
5	Randa	NGS	16	Markurdi	DS
6	Suleja	SGS	17	Omua-Aran	DS
7	Jalingo	NGS	18	Okenne	DS
8	Anyingba	SGS	19	Umudike	FZ
9	Uromi	FZ	20	Ado-Ekiti	FZ
10	Offa	DS	21	Gboko	DS
11	Zaria	NGS			

Note: NGS: Northern Guinea Savanna; SGS: Southern Guinea Savanna; DS: Derived Savanna; FZ: ForestZone

Table 2:Disease severity rating scale 0-9

Grade	Disease severity	Host response
0	No lesion observed	Highly Resistant
1	Small brown specks of pin point size	Resistant
2	Small roundish to slightly elongated, necrotic gray spots, about 1-2 mm in diameter, with a distinct brown margin. Lesions are mostly found on the lower leaves	Moderately Resistant
3	Lesion type same as in 2, but significant number of lesions on the upper leaves	Moderately Resistant
4	Typical susceptible blast lesions, 3 mm or longer infecting less than 4% of leaf area	Moderately Susceptible
5	Typical susceptible blast lesions of 3mm or longer infecting 4-10% of the leaf area	Moderately Susceptible
6	Typical susceptible blast lesions of 3 mm or longer infecting 11-25% of the leaf area	Susceptible
7	Typical susceptible blast lesions of 3 mm or longer infecting 26-50% of the leaf area	Susceptible
8	Typical susceptible blast lesions of 3 mm or longer infecting 51-75% of the leaf area many leaves are dead	Highly Susceptible
9	Typical susceptible blast lesions of 3 mm or longer infecting more than 75% leaf area affected	Highly Susceptible

RESULTS AND DISCUSSION

Soil Properties of Experimental Sites

The nature and state of soil has a great influence on the growth and development of plant grown on it. The soil physiochemical properties of the experimental sites is shown in Table 3. The soils in the three experimental environments are slightly acidic. The pH ranges for the soil across three experimental sites will still permissible for plant nutrients uptake [23]. The textural class of the soil at the three environments was sandy loam. This class of soil has ability to hold water and allow easy penetration of plant roots. The total N, organic matter content and available phosphorus values were low at the three locations compared to the 1.5-2.0 g kg^{-1},25-30 g $kg^{-1}$and 10-15 mg kg^{-1} critical ranges of total N, organic matter and available phosphorus respectively as established for soils in Nigeria [24].

Table 3: The soil physiochemical properties of the experimental sites.

Properties	Environments		
	Ondo-City	Ado-Ekiti	Oke-Ako
Sand (%)	59.4	64.3	60.6
Clay (%)	19.6	18.4	21.2
Silt (%)	21.0	18.3	18.1
Textural Class	Sandy loam	Sandy loam	Sandy loam
pH (H20)	5.78	5.66	5.71
Carbon (%)	0.91	0.80	0.84
Organic Matter (%)	1.50	1.43	1.63
Nitrogen (%)	0.11	0.09	0.09
Phosphorus ($mgkg^{-1}$)	9.17	7.19	9.19
Ca^{2+} ($cmolkg^{-1}$)	1.21	1.69	1.73
Mg^{2+} ($cmolkg^{-1}$)	0.66	0.63	0.66

Table 4 presents the mean performance of the parameters taken for the 21 sweet potato accessions evaluated against early blight disease across the three environments. The result shows that Offa (4.88) had the highest mean number of roots per plant followed by Umudike, Jalingo, Uromi and Okenne with the mean number of roots per plants of 3.16, 3.01, 3.00 and 2.96 respectively while Ado-Ekiti recorded the least mean number of roots per plant followed by Markurdi and Kano accordingly. It was also observed that Ayingba had the highest mean above ground fresh biomass yield per plant (3,226.40g) followed by Omu-aran, Suleja and Umudike respectively. The differences observed among the traits studied within the accessions could be a result of variability in the genetic make-up of the accessions [25].The accessions with high above ground fresh biomass yield could serve as a multipurpose crop for both fodder and food crop.

Table 5 present the analysis of variance for the parameters taken for the 21 sweet potato accessions evaluated across the three environments against early blight disease. The accessions were significantly different from each other ($P<0.05$) for all the parameters taken. The level of significant indicated the level of genetic variability among the accessions [25]. The degree of variability among the accessions shows that improvement can be made in these accessions. Similar report was made by [26]in number of roots per plants in sweet potato.For the environments, the parameters studied were significant though at different levels except for days to 50% flowering. The level of significant across the environments could be a result of differences in the soil properties and the climate variables across the different agro-ecological zones (Ibiride, 2019). [27] reported some levels of significance in with the grain yield, number of leaves per plant, 50% days to flowering and number of pods per plant in some African yam bean grown in different environments. The result shows that accession x environment for all the parameters studied were significantly different ($P<0.05$). This shows that these accessions were not consistent across the environments. The finding from this research is in agreement with the finding of [28] who reported accessions instability in cowpea.

Table 4: Mean performance of parameters taken from 21 Sweet Potato accessions screened against Early Blight disease.

S/n	Accession	D50%F	$FRWP^{-1}$	NRP^{-1}	$NMBP^{-1}$	$AGRBYP^{-1}$
1	Sokoto	127.28^{a}	332.54^{b}	4.84^{a}	4.89^{bcd}	1400.75^{fg}
2	Ilorin	108.44^{bcde}	97.51^{e}	2.03^{ef}	4.00^{cd}	1663.61^{ef}
3	Mokwa	117.24^{abc}	187.46^{d}	2.41^{cde}	3.22^{d}	1586.50^{efg}
4	Kujama	125.06^{a}	216.46^{d}	2.40^{de}	3.15^{d}	1245.08^{gh}
5	Randa	106.06^{cde}	39.77^{fg}	1.57^{fgh}	3.36^{d}	1030.49^{h}
6	Suleja	115.76^{abc}	39.86^{fg}	1.29^{gh}	8.08^{a}	3058.96^{ab}
7	Jalingo	110.97^{bcd}	450.39^{a}	3.00^{b}	4.69^{bcd}	2640.01^{cd}
8	Ayugba	$100.\ 83^{de}$	276.30^{c}	2.84^{bcd}	6.24^{ab}	3226.40^{a}
9	Uromi	123.64^{a}	303.90^{bc}	3.00^{bc}	4.76^{bcd}	2313.50^{d}
10	Anyingba	118.39^{ab}	51.55^{f}	1.88^{efg}	3.21^{d}	2774.99^{bc}
11	Zaria	108.50^{bcde}	189.50^{d}	2.04^{ef}	5.14^{bcd}	2832.68^{bc}
12	Kano	103.77^{de}	36.95^{fg}	1.22^{h}	5.96^{abc}	2789.92^{bc}
13	Iresi	98.80^{e}	11.63^{g}	0.48^{i}	3.09^{d}	1806.69^{e}
14	Ondo City	116.28^{abc}	218.11^{d}	2.39^{de}	3.12^{d}	2316.33^{d}
15	Abeokuta	124.12^{a}	296.23^{bc}	2.92^{bc}	5.09^{bcd}	1673.71^{ef}
16	Markurdi	103.28^{de}	40.18^{fg}	1.21^{h}	7.06^{a}	2891.93^{bc}
17	Omu-Aran	109.38^{bcd}	186.11^{d}	2.01^{ef}	3.9^{6cd}	3201.41^{a}
18	Okenne	126.01^{a}	220.11^{d}	2.96^{bcd}	6.11^{ab}	2672.23^{cd}
19	Umudike	107.02^{bcde}	219.11^{d}	3.16^{b}	4.63^{bcd}	3056.38^{ab}
20	Ado-Ekiti	119.11^{ab}	39.38^{fg}	1.14^{h}	4.63^{bcd}	1009.80^{h}
21	Gboko	102.97^{de}	53.19^{f}	$1.56f^{gh}$	3.34^{d}	1036.32^{h}

Means with the same letter(s) in each Column are not significantly different ($P<0.05$) according to Duncan's Multiple Range Test (DMRT).

SoV: Source of Variance; D50%F: Days to 50% flowering; $FRWP^{-1}$: Weight of fresh root per plant; NRP^{-1}: Number of root per plant; $NMBP^{-1}$: Number of branches per plant; $AGRBYP^{-1}$: Above ground fresh biomass yield per plant

Table 5: Analysis of variance for parameters taken for the 21 sweet potato accessions across the three environments.

SoV	Df	D50%F	FRWP-1	NRP-1	NMBP-1	AGFBYP-
Rep	2	59.09	106.47	0.01	0.64	24674.53
Accessions	20	522.01^{**}	1165.99^{**}	8.82^{**}	13.59^{**}	340492.08^{**}
Env.	2	36.65	1540.77^{xx}	0.71^{x}	1.35	148283.46^{**}
Acc. X Env.	20	25.32**	471.05^{**}	0.21^{**}	1.44^{**}	2456.98^{xx}
Total	144					

, ** significant at 5% and 1% level respectively

SoV: Source of Variance; D50F: Days to 50% flowering;FRWP-1:Weight of fresh root per plant;NRP-1: Number of root per plant; NMBP-1: Number of branches per plant; AGRBYP-1 Above ground fresh biomass yield per plant

The level of early blight disease severity recorded for the 21 sweet potato accession studied is shown in Table 6 and summarized in Table 7. The results shows that none of the accessions screened is highly resistant while four of the accessions were resistant ,six (6), three (3) and four (4) accession were found to be moderately resistant, susceptible, moderately susceptible and highly susceptible accordingly as shown in table 7. The different levels of these sweet potato accessions susceptibility to early blight disease could be a result genetic composition of each accession. These indicated that some accession carries gene(s) that are resistant to the disease. This findings is in agreement with the work of [29] who screened 25 Uganda's sweet potato accessions and observed that none of the accession is highly resistant while some are resistant, moderately resistant, susceptible, moderately susceptible and highly susceptible.

The resistant accessions can be exploited in a breeding programme for the development of early blight disease-resistant for commercial cultivars. According to [30] development of a new cultivar during a plant breeding programme involves hybridization of accessions with desired traits.

Table 6: Summary of Sweet Potato accessions blast severity recorded in Ado Ekiti using standard evaluation system of international potato centre

Accessions	Host Response	Accessions	Host Response
Sokoto	Highly Susceptible	Kano	Susceptible
Ilorin	Moderately Resistant	Iresi	Resistant
Mokwa	Highly Susceptible	Ondo City	Moderately Susceptible
Kujama	Moderately Susceptible	Abeokuta	Moderately Susceptible
Randa	Highly Susceptible	Markurdi	Moderately Resistant
Suleja	Highly Susceptible	Omu-Aran	Susceptible
Jalingo	Moderately Resistant	Okenne	Moderately Resistant
Ayugba	Moderately Resistant	Umudike	Resistant
Uromi	Moderately Resistant	Ado-Ekiti	Susceptible
Offa	Resistant	Gboko	Moderately Resistant
Zaria	Resistant		

Table 7Summary of Sweet Potato accessions blast severity recorded in Ado Ekiti using standard evaluation system of international potato centre

Score rating	Disease reaction	Accessions
0	Highly resistant	-
1	Resistant	Offa, Zaria, Iresi, Umudike.
2-3	Moderately resistant	Ilorin, Jalingo, Ayingba, Uromi, Okenne, Goko.
4-5	Susceptible	Kano, Markurdi, Omu-Aran, Ado-Ekiti.
6-7	Moderately susceptible	Kijama, Ondo City, Abeokuta.
8-9	Highly Susceptible	Sokoto, Mokwa, Randa, Suleja.

Conclusion.

This research revealed thatthat none of the prominent sweet potato growing different part of Nigeria were highly resistant to *Alternaria solani* disease under field artificial inoculation in three diverse savanna agro-ecological zones. Only four of the 21 accessions were resistant while six were moderately resistant. Moreover, two of the accessions that were resistant gave high root yield (Offa and Umudike) while the other two accessions gave low root yield. The resistant and moderately resistant accessions with high mean root yield could be exploited in disease resistance breeding programs for the development of sweet potatoes cultivars and hybrids that are resistant to Alternaria solani with high root. Sweet potato growers should be growing the accessions from Offa and Umudike which are resistant to *Alternaria solani* with high root yield to reduce the cost of production and increase yield pending the time sweet potato that are resistant to*Alternaria solani*be will readily available and affordable.

Author's contribution: Gbenga Oluwayomi Agbowuro conceived the idea, analysis the data **and** did the final editing**.** Moses Jimoh Falade set up the experiment, collected data and work on the research article write up**.**

Acknowledgments

We would like to appreciate the Department of Crop, Horticulture and Landscape Design, Ekiti State University, Ado-Ekiti for using their visual library.

Declarations

Limitations of the study

None

Competing Interests

The authors declared that no conflict of interest exists.

Funding source

None

REFERENCES

1. Singh, G. Plant Systematics: An Integrated Approach. Boca Raton, FL: CRC Press, 2019; 568.
2. Mwanga ROM, Odongo B, Ocitti p_Obwoya C, Gibson RW, Smit NEJM, Carey EE. Release of five sweetpotato cultivars in Uganda. Hort. Science 2001; 36:385–386.
3. Amagloh FC, Yada B, Tumuhimbise GA, Amagloh FK, Kaaya AN. The potential of sweet potato as a functional food in sub-saharan Africa and its implications for health: a review. Molecules. 2021; 26: 2971. doi: 10.3390/ molecules26102971
4. Ecocrop (2010). Ecocrop database. FAOweb.http://ecocrop.fao.org/ecocrop/srv/ey/home.
5. Mu T, Singh J. Sweet Potato: Chemistry, Processing, and Nutrition. London: Academic Press, 2019;400. doi: 10.1016/C2016-0-05204-X
6. Alam MK. A comprehensive review of sweet potato (*Ipomoea batatas* [L.] Lam): revisiting the associated health benefits. Trends Food Sci. Technol. 115, 2021:512–529.
7. Chen H, Sun J, Liu J, Gou Y, Zhang X, Wu X. Structural characterization and anti-inflammatory activity of alkali-soluble polysaccharides from purple sweet potato. Int. J. Biol. Macromol. 2019; 131, 484–494. doi: 10.1016/j.ijbiomac.2019.03.126

8. Yuan B, Yang XQ, Kou M, Lu CY, Wang YY, Peng J. Selenylation of polysaccharide from the sweet potato and evaluation of antioxidant, antitumor, and antidiabetic activities. J. Agric. Food Chem. 2017; 65: 605–617. doi: 10.1021/acs.jafc.6b04788
9. Kim HJ, Koo KA, Park WS, Kang DM, Kim HS, Lee BY. (2020). Anti-obesity activity of anthocyanin and carotenoid extracts fromcolor-fleshed sweet potatoes. J. Food Biochem.2020; 44: e13438. doi: 10.1111/jfbc.13438
10. Agbowuro GO, Ayeyo ME, Awoyemi SO, Aigbokhan OF. Screening of upland-rice landraces for resistance to rice blast disease (*Magnaporthe oryzae*). Journal of Pure and Applied Agriculture, 2021;6(2):9-16.
11. Chalwe JM, Adebola P, Pillay M. Assessing the genetic diversity of *Alternaria bataticola* in South Africa using molecular markers. Asia J Appl Sci. 2017; 5(2).
12. Osiru M, Adipala E, Olanya OM, Lemaca E. Occurrences of Alternaria leaf petiole and stem blight on sweet potato in Uganda. Plant Pathol J. 2007; 6(2):112-119.
13. Anginyah TJ, Nark RD, Caray EE, Njeru R. Etiology, effect of soil pH and sweet potato varietal reaction to Alternaria leaf petiole and stem blight in Kenya. Afr J Crop Sci. 2001; 9(1):287-299.
14. Ilondu EM. Etiology and assessment of leaf spot disease of sweet potato (*Ipomea batatas* L) Lam. In selected farms in Nigeria. Agric Biol J Am. 2012; 4(4):474-484.
15. Amadioha AC, Kenkwo PC, Markson AA. Fungitoxic potentials of extracts of plant origin against fungal root rot of cassava (*Manihot esculenta* Crantz) in storage. Ann Res Rev Biol. 2019; 31(1):1-9.
16. Agbowuro GO, Afolabi MS, Olamiriki EF, Awoyemi SO. Rice blast disease (*Magnaporthe oryzae*): A menace to rice production and humanity. International Journal of Pathogen*.* 2020; *4*(3):32- 39.
17. Jimoh FM, Oluwayomi AG. (2023). Breeding for Late Blight Disease Resistance Varieties in Potato: A Strategic Approach for Food Security and Sustainability. International Journal of Pathogen Research, 2023; *12*(6): 31–36. https://doi.org/10.9734/ijpr/2023/v12i6250
18. Namrata RPS, Verma R, Bisen R, Singh R, Teli B. Inheritance of blast disease resistance in the cross hur 3022 x tetep of rice (*Oryza sativa* L.) Journal of Experimental Biology and Agricultural Sciences, 2019; 7(6):529 – 535.
19. Harlapur SI, Kulkarni MS, Wali MC, Kulkarni S. Evaluation of plant extracts, bio-agents and fungicides against *Exserohilum turcicum* (Pass.) Leonard and Suggs. causing turcicum leaf blight of maize. Journal of Agricultural Sciences, 2007;20: 541-544.
20. Jia Y, Valent B, Lee FN. Determination of host responses to *Magnaporthe grisea* on detached rice leaves using a spot inoculation method. Plant Disease,2003; 87:129– 133.
21. Enyiukwu DN, Amadioha AC, Ononuju CC. Significance of cowpea leaves for human consumption. *Greener Trends Food Sci Nutr.*, 2018;1(1):001-010.
22. STAR, version 2.0.1. Biometrics and Breeding Informatics, PBGB Division, International Rice Research Institute, LosBaños, Laguna, 2014.
23. Golla AS. Soil acidity and its management options in Ethiopia: A review. *International Journal of Scientific Research and Management*. 2019; *7*(11):1429- 1440.
24. Agboola AA, Corey RB. The relationship between soil pH, organic matter, available P, exchangeable K, Ca, Mg and nine elements in maize tissue. Soil Science*,*1973;115: 367-357.
25. Akinyosoye ST, Adetumbi JA, Amusa OD, Agbeleye A, Anjorin F, Olowolafe MO, Omodele T. Bivariate analysis of the genetic variability among some accessions of African yam bean (*Sphenostylis stenocarpa* (Hochst ex A. Rich) Harms). Acta agriculturae Slovenica, 2017;109.3.02.
26. Thiyagn D, Rafii MY, Mahmud TMM, Latif MA, Malek MA, Sentor G. Genetic variability in Sweet potato (Ipomeoa babatas Lam.) genotypes selected for vegetable use. Journal of Food, Agriculture and Environment. 2013; 11(2): 340-344
27. Agbowuro GO, Salami AE, Aluko M, Olajide OO. Phenotypic variability among African yam bean landrace accessions from different agro-ecologies of Nigeria. Nigerian Agricultural Journal 2021; 52 (1): 70-76.
28. Ajayi AT, Gbadamosi AE. Genetic variability, character association and yield potentials of twenty five accessions of cowpea (*Vigna unguiculata* L. Walp). Journal of Pure and Applied Agriculture. 2020;5(2): 1-16.

29. Sseruwu G, Mary N, Agnes A, George K, Ian B. Evaluation of Sweetpotato (*Ipomoea batatas* (L.) Lam.) Genotypes for Resistance to Alternaria Leaf Petiole and Stem Blight (*Alternaria* spp.) in Uganda. Journal of Agricultural Science. 2020;12 (10): 263-274.

30. Joshi BK, Bimb HP, Parajuli G, Chaudhary B. (2009). Molecular tagging, allele mining and marker aided breeding for blast resistance in rice. BSN e-Bulletin, 2009; 1: 1-23.