ZIBELINE INTERNATIONAL PUBLISHING

Malaysian Journal of Sustainable Agriculture (MJSA)

DOI: http://doi.org/10.26480/mjsa.01.2021.16.20

ISSN: 2521-2931 (Print)
ISSN: 2521-294X (Online)
CODEN: MJSAEJ

Malaysian Journal of Sustainable Agriculture MJSA

CrossMark

RESEARCH ARTICLE

PROMISING EARLY PLANTING AND STRESS-TOLERANT POTATO GENOTYPES FOR NORTHERN BANGLADESH

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ARTICLE DETAILS

Article History:

Received 21 October 2020
Accepted 25 November 2020
Available online 07 December 2020

ABSTRACT

Potato is the third major food crop in the world. In Northern Bangladesh, potato production outside the regular growing season can contribute to farmers' profit and prices can be very favorable as consumers' demand for potatoes is greater than the decreased, off-season supply. However, potato production may be negatively affected by increased pest and disease pressure and higher soil temperature. We hypothesized that some potato varieties would have smaller tuber yield reduction when they are grown outside the normal season. The objective of this experiment was to find out promising genotypes for earlier cultivation prior to mid of November, cultivation in northern regions of Bangladesh. The trials, corresponding to very early, early, normal and late growing seasons were planted using a randomized complete block design with three replications. Germination percent, plant height, stems per hill, marketable tuber yield at 65 days, marketable tuber yield at 90 days were recorded. For yield and components of yield contributing characters Clone 13.17, BARI Alu 7(Diamant) and Arizona outperformed in all growing condition and had wider adaptability and stability of tuber yield based on Additive main effects and multiplicative interaction (AMMI).

KEYWORDS

Potato, Growing season, Region, Yield, Stable.

1. INTRODUCTION

Potato is the number one vegetable crop, have higher economic returns than cereals such as High Yielding Variety (HYV) rice. Potato yields are still comparatively low in Bangladesh. This is caused by numerous factors, the most important of which include low levels of applied technology and mechanization, fragmentation of production plots, production under dry conditions with high summer temperatures, and limited use of certified seed material, used on only 10-12% of the planted area. In addition, potato yields in Bangladesh are very unstable and very susceptible to abiotic stresses. Similar conditions limiting potato production were found in Montenegro (Jovovic et al.,2011). The appropriate selection of varieties can help diminish the adverse impacts on production, especially the water-air regime of soil, high air temperatures and short growing season for potato cultivation (Jovovic et al., 2002). Potatoes for human consumption must have acceptable organoleptic quality in order to meet consumer demands. The tubers should be nicely shaped with shallow buds, and be healthy, strong and uniformly sized, Tuber skin and flesh color are not essential quality components, but significantly influence customers' interest. Variety productivity is a function of its ability to provide stable high yields in different agro-ecological conditions. Therefore, it is very important to develop varieties that will be able to provide consistent high yields across a wide range of environmental conditions. Principal component analysis (PCA) can improve selection efficiency in crop improvement programs (Johnson and Wichern, 2007). Through this method, fewer variables explaining variations among individuals can be screened among various characters (Shimelis et al., 2013). Principal component analysis helps to provide a three-dimensional representation of genotype environment pattern which allows the response of each environment to be directly identified (Mahajan and Prasad, 1986). In addition, the AMMI model can be used to identify high quality and stable genotypes under different environmental conditions. AMMI combined with PCA can be used to systematically evaluate different varieties of potatoes in different environments is conditions provide stable yields, either on a higher or lower level. When farmers in Northern Bangladesh plant potatoes early, yields are lower than when they are planted in the normal season. Higher temperatures restrict yield by reducing the partitioning of assimilates to tubels, Whether or not potato plant will form tubers depends largely on the minimum night temperature and not on the average daily temperature. Potatoes planted prior to mid-October typically have lower yields due to high temperatures. However, farmers will plant this early because higher prices for earlier potatoes can offset the lower yields. Identifying suitable varieties for early planting from the existing genetic materials of Tuber Crop Research Center (TCRC) may provide farmers with higher yields and help ensure food security in Bangladesh. Therefore, the objective of this study was to investigate the potential of eleven potato genotypes and examine their reactions to the specific conditions of Northern regions of Bangladesh, in order to identify genotypes that high and stable yields. The second objective of this experiment is expected to extend potato cultivation to non-traditional

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Cite the Article: M.N. Amin, B.C. Kundub, M. Rahman, M.M. Rahman and M.M. Uddin (2021). Promising Early Planting and Stress-Tolerant Potato Genotypes For Northern Bangladesh. *Malaysian Journal of Sustainable Agriculture, 5(1): 16-20.*

areas and seasons, thus bringing more area under potato cultivation in Bangladesh.

2. Materials and Methods

Eleven genotypes of potato including two clones '13.17' and '13.19', six exotic cultivars 'Arizona', 'Deliared', 'Hind II', 'HZD1249', 'Ottawa', and 'Prada', two late blight tolerant cultivars 'Twinner' and 'Twister', and one popular local variety 'BARI Alu 7'(Diamant) were evaluated at the Breeder Seed Production Center, Debiganj (26.107852°N,88.773642°E,36 masl) Bangladesh during the 2019-2020 crop year. Plots were 5 m^{-2} and were planted on 60cm x 25cm centers using a Randomized complete block design with 3 replicates. The entire experiment was planted on each of four planting dates: 22 September 2019; 07 October 2019, 20 November 2019, and 31 December 2019. These planting dates are termed very early, early, normal, and late, respectively. Fertilizers: urea,325 kg ha^{-1}, trisodium phosphate,320 kg ha^{-1}, muriate of potash,250 kg ha^{-1}, and gypsum,120 kg ha^{-1} were applied. Half of urea and full dose of other fertilizers were applied before planting the seed in furrows and mixed properly with the soil. The rest amount of urea was applied as side dressing at 35 days after planting. Necessary intercultural operations were done as per TCRC recommendation. Data recorded included % emergence, plant height, number of stems plant^{-1}, number of tubers plant^{-1}, weight of all the tubers of each plant weight of tuber plant^{-1} and tuber yield (t ha^{-1}). Plots were evaluated for presence of mites (*Polyphagotarsonemus latus)*, Black leg (*Pectobacterium carotovorum* subsp. *Carotovorum)*, Rhizoctonia (*Rhizoctonia* solani Kühn.) and Late Blight (Phytophthora infestans) at 60 days after planting (vegetative stage). Data were analyzed using R statistical software using agricolae package. AMMI utilize ordinary ANOVA to estimate the main effects i.e. additive part and Principal Component Analysis (PCA) to estimate the non-additive error which is not counted by the ANOVA. Temperature and relative humidity data were obtained from temperature sensor (James et al., 1971) (Figure 1) located 3 meters above the ground within each plot. Growing degree days (GDD) were calculated throughout the season for each planting date (Table 1) using the formula GDD = [(min T + max T)/2-Tb]. Tb, the base temperature/or minimum threshold temperature, for potato is 4.5 (Narayan et al., 2014). Disease and insect scoring (at 60 Days after planting) was done on the basis of disease progress curve and percent yield loss following (James et al., 1971).

Table 1: Growing Degree Days (GDD), Temperature and Rainfall for four different planting dates

	Very Early	Early	Normal	Late
Growing Degree Days	1672.57	1716.53	1479.32	1468.56
Min Temp	7.041	7.041	6.81	6.81
Max Temp	35.904	35.904	35.47	33.36
Rainfall,mm	29.4mm	15.6mm	6mm	68.4 mm

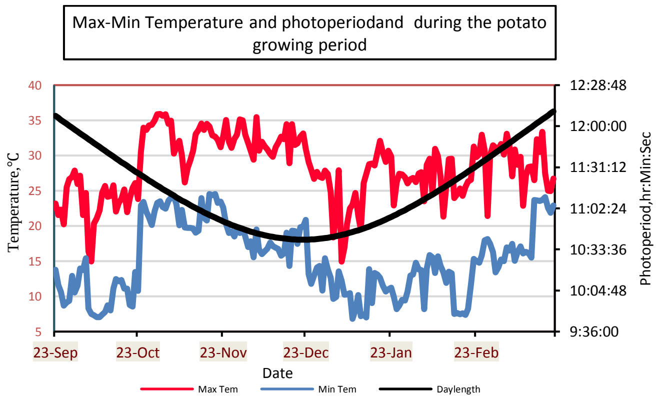

Figure 1: Max-Min Temperature and photoperiod during the potato growing period

3. Results

Analysis of variance indicated that there was significant genotypic variance among genotypes for tuber yield. There was significant variation between genotypes, environments, E+(G×E), Environment(linear), and G×E(linear) mean sums of squares (Table 2). The normal planting date had the highest tuber yield (42.44 t ha^{-1}) followed by late season (26.26 t ha^{-1}). Among the eleven genotypes, the mean tuber yield of Arizona, 32.29 t ha^{-1}, was significantly greater across planting dates and significantly greater than most genotypes at the normal planting date (Table 3). Because of the significant variation in genotype x environment interaction, the additive main effects and multiplicative interaction (AMMI) model was used to identify genotypes with stable, marketable tuber yield across environments. The estimate of deviations from regression(S^2d) implies the degree of reliance which should be put to linear regression in explanation of the data. If these values are significantly deviating from zero, the expected phenotype cannot be predicted satisfactorily. When, deviations(S^2d) are not significant the assumption may be drawn by the joint consideration of mean, yield and regression coefficient (bi) values (Finlay and Wilkinson, 1963 and Eberhart and Russell, 1966).

Table 2: Mean squares of combined analysis of variance of marketable tuber yield(tha^{-1}) of 11 genotypes evaluated across seasons

Parameters	df	Mean Sum of Square
Season (Planting)	3	6643.4***
Rep (Planting)	8	39.6
Genotype	10	197.4***
Planting: genotype	30	161.3***
Residuals (error)	80	36.8

Table 3: Mean and AMMI stability of marketable tubers (tha^{-1}) of 11 genotypes evaluated over four planting dates during the 2019-2020 cropping year.

Variety	Planting Date				Mean
	Very Early	Normal	Late	Early	
13.17	11.43	38.98	26.1	20.11	24.16
13.19	6.971	43.6	22.32	24.7	24.4
Arizona	8.443	59.6	36.36	24.77	32.29
Deliared	4.03	21.51	23.81	15.12	16.12
Diamant	6.339	37.22	23.56	18.48	21.4
HindII	8.2	55.69	21.65	20.53	26.52
HZD-1249	17.2	49.96	10.81	29.35	26.83
Ottawa	8.863	43	35.47	16.7	26.01
Prada	8.879	37.64	15.41	27.49	22.36
Twinner	4.557	34	36.64	18.77	23.49
Twister	3.492	45.64	36.73	22.35	27.05
Site Means	8.037	42.44	26.26	21.67	24.6
Site index	11.54	2.544	3.745	7.605	6.358

To generate a principal component of a biplot, genotype scores were multiplied by a set of environment scores. A high PC1 value and a low PC2 value was associated with genotypic stability. Genotypes with PC1 scores greater than zero were considered as high yielding, stable and genotypes with PC1 scores less than zero were considered as low yielding, unstable yielding (Figure 2). Grouping of lines in 3D biplots had much more conformity for each principal component with the results from 3D biplot and showed more importance of the first principal component, which justifies much of total variance (Figure 2). The PCA revealed three main principal components representing 100 % of total variance among the 11 genotypes of potato (Table 4). The genotypes Deliared (16.12 t ha^{-1}) and Twinner (23.49 t ha^{-1}) performed well in the late planting period and had below average response with nonsignificant bi values (0.517, 0.889) (Table 4). Principal component scores, regression coefficient (bi) and deviation from regression (S^2di) of the individual genotypes are shown in (Table 4). However, deviation from regression line was found to be non-significant for all genotypes. Genotype Diamant had overall mean (21.4 tha^{-1}) non-significant 'bi'(0.90) and 'S^2di' value (0.086) and could be predicted as stable. In addition, the genotypes 13.17 had *i.e.,* overall mean (24.16t/ha), non-significant 'bi'(0.812) and 'S^2di' value (0.537) and Arizona overall mean (32.29 t/ha), non-significant 'bi'(1.50) and 'S^2di' value (1.93) also somewhat satisfy the parameters of stability (Table 4). Thus, Diamant, Clone 13.17 and Arizona genotypes could also be predicted as stable genotypes. Black leg and Mite damage were a serious problem in early planted potato crop. Most of the genotypes were susceptible to those diseases (Table 5). In Normal and late planted crop, late blight and rhizoctonia were a threat but schedule spray reduced the risk of damage. In addition, Twister and Twinner were found tolerant to late blight disease (Table 5). Hence, these four genotypes can be recommended for general cultivation in the Northern region of Bangladesh after detailed and further testing.

Table 4: Environment wise performance along with stability parameters for marketable yield at 90 days in potato

Variety	PC1	PC2	PC3	s^2d_i	bi	s^2d_i	AR	SD
13.17	-0.164	0.769	-1.117	0.537	0.812	2	3.56	2.28
13.19	0.780	0.053	0.958	3.736	1.038	4	3.69	1.85
Arizona	-0.182	-2.678	0.380	1.938	1.508	3	4.38	3.14
Deliared	-1.540	2.445	-0.262	10.573	0.517	5	7.88	3.48
Diamant	-0.162	0.462	-0.304	0.086	0.900	1	3.38	3.72
HindII	1.588	-2.073	-0.641	13.760	1.380	7	6.63	1.82
HZD-1249	3.574	0.736	-0.507	58.755	0.891	11	8.25	3.21
Ottawa	-1.561	-0.637	-1.389	14.504	1.043	8	5.06	1.69
Prada	1.614	1.589	1.288	17.881	0.777	9	7.69	1.92
Twinner	-2.436	0.501	0.347	26.719	0.889	10	8.56	1.82
Twister	-1.510	-1.166	1.247	11.531	1.245	6	6.38	2.68
Early	1.430	1.918	2.106					
Late	-4.823	-0.565	0.058					
Normal	2.219	-3.712	-0.181					
Very	1.175	2.359	-1.983					

Principal component (PC), Deviation from regression(S^2di), Regression coefficient(bi), Kang's rank-sum (AR), average of sum of ranks (ASR), and standard deviation (SD)

Table 5: Disease Reactions in different potato planting period

Variety	Vary early planting				Early planting				Normal planting				Late planting			
	Mite		Blackleg		Mite		Black leg		Late blight		Rhizoctonia		Late blight		Rhizoctonia	
	Incidence, %	Severity, %	Incidence, %	Severity, %	Incidence, %	Severity, %	Incidence, %	Severity, %	Incidence, %	Severity, %	Incidence, %	Severity, %	Incidence, %	Severity, %	Incidence, %	Severity, %
13.17	9.67	0.33	0	0	7.14	0.33	0	0	0.67	0.33	0	0	1.33	0.67	0	0
13.19	19.58	1.66	0	0	16.67	1.33	0	0	0.33	0.23	0	0	1.00	0.33	0	0
Arizona	14.33	1.00	6.33	0.67	13.53	0.66	3.33	0.67	0.33	0.13	0	0	0.66	0.24	0	0
Deliared	10.47	0.67	3.33	0.67	8.33	0.33	1.33	0.33	0.23	0.12	0	0	0.33	0.12	0	0
Hind II	7.63	0.67	1.67	0.33	5.63	0.33	1.67	0.33	0.46	0.15	0	0	0.66	0.22	0.33	0.11
HZ06-1249	16.38	1.67	2.67	0.67	14.38	1.33	1.67	0.33	0.33	0.08	0	0	0.33	0.11	0	0
Ottowa	7.76	0.67	1.33	0.33	4.76	0.33	1.00	0.33	0.11	0.14	0	0	1.67	0.66	0.33	0.14
Prada	7.69	0.97	1.00	0.33	4.33	0.33	0.67	0.33	0.33	0.12	0	0	1.00	0.33	0	0
Twinner	26.19	1.67	0.87	0.33	15.19	1.33	0.33	0.13	0	0	0	0	0	0	0	0
Twister	9.52	1.33	0.67	0.33	6.67	0.33	0	0	0	0	0	0	0	0	0	0
Diamant	20.25	1.33	0.67	0.33	20.25	1.33	0	0	0.67	0.33	0.33	0.13	1.0	0.33		

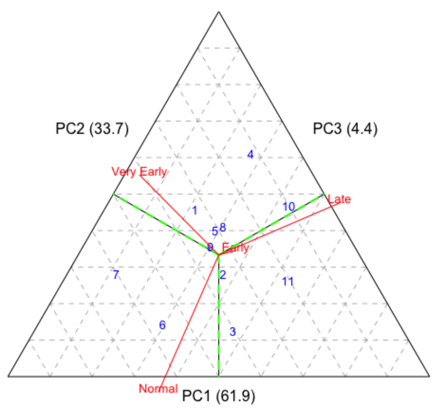

Figure 2: AMMI 1 triplot for yield (ton ha^{-1}) of 11 potato genotypes and four planting dates using genotypic and environmental scores. (Where 1. Clone 13.17; 2. Clone 13.19; 3. Arizona; 4. Deliared; 5. Diamant; 6. HindII; 7. HZD1249; 8. Ottawa; 9. Prada; 10. Twinner; 11.Twister)

4. Discussion

There is a need for high and stable yielding potato varieties to meet increased demand for food in Asia and Africa. As a result of changing agro-climatic conditions in Bangladesh, suitable potato varieties will be required for planting early and to enable potatoes to be incorporated into diversified cropping systems. These potato varieties will provide flexibility in planting and harvesting times without exerting additional pressure on declining resources. The northern region, which is located at the highest altitude of Bangladesh, proved to be the most suitable area for the production of early and medium early varieties of potatoes (Byuro, 2011). We found that temperature and precipitation in September had significant influence on declining tuber yield in the analyzed series of field trials. Similar results were obtained by, who found that cultivars behaved differently under higher temperature and longer photoperiod, depending on their earliness behavior. Barman et al., (2019) noted that potatoes sown during the first week of December had higher tuber yield and quality as compared to earlier or later sown potatoes (Table 4). Hancock et al., (2014) found that temperature has a clear effect on the assimilate partition in potato which helps haulm growth and inhibits tuber growth. Further, most potato varieties required more than 800 GDDs to reach maturity but a minimum of 70-90 days of favorable cool temperature is required for profitable yields. This Principal component (PC) was very important to select high yielding clones and parents for breeding program. In the evaluation of diversity among potato cultivars using agro-morphological and yield components we found maximum 61.9% of variation was explained by the first principal component. Ahmadizadeh and Felenji (2011) observed that three components explained 80.1% of the total variation among traits. The authors reported that the first PC was highly correlated with yield, tuber weight, dry matter content and harvest index.

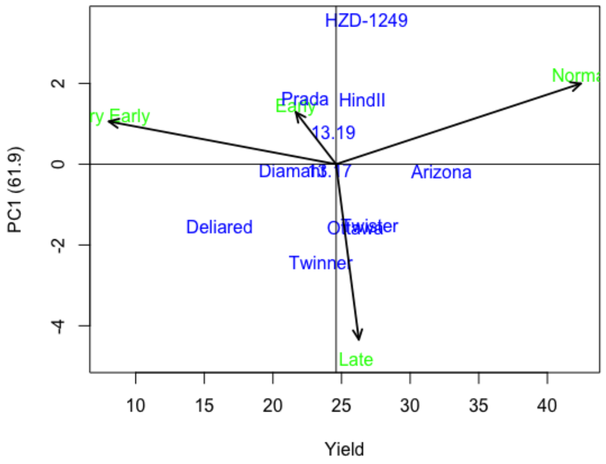

Figure 3: AMMI 1 biplot of 11 potato genotypes evaluated in four planting dates for marketable tubers(tha^{-1}) at Debiganj, Panchagarh, Bangladesh

The distance from the origin (0,0) is indicative of the amount of interaction that was exhibited by genotypes either over environments or environments over genotypes, van Eeuwijk et al., (2002). We found that Diamant and Clone 13.17 had low genotype-by-environment interaction and close to the origin., proposed using the "regression coefficient"(bi) to evaluate genotype adaptability and the "regression deviation"(S^2di) to evaluate the stability, which indicates the probability of the genotypes to deviations in the environment. In our results, Diamant, Clone 13.17 and Arizona genotypes had high mean yields, regression coefficients equal to one (bi = 1), and small regression deviation mean square (S^2di= 0) and would be predicted as stable genotypes. In a study in New York, Tai (1971) reported Katahdin as a stable variety using a similar regression model. Hassanpanah and Hassan (2014) found three superior clones with good yield and quality traits out of eighteen promising potato clones in Ardabil province of Iran. Further, Mukherjee and Naskar, (2013) conducted an experiment evaluating phenotypic stability of tuber yield in sweet potato and identified a suitable variety for Orissa State using a regression model. Based on our study, we recommend Diamant, Clone 13.17 and Arizona for early planting in the northern region of Bangladesh using similar regression model. Those early planting potato varieties will explore sustainable cultivation practices, meet market demand and impact of introducing potato on cereal-based cropping system.

5. Conclusion

The variety Prada was adapted to early season planting while genotypes Hind II, Twister and Ottawa were found suitable for the normal season. Diamant, Clone 13.17 and Arizona were selected for wide production as they had stable and high mean marketable tuber yields across seasons. Early planting potato genotypes Diamant, Clone 13.17 and Arizona with a positive response to an expected range of temperature variation seems pertinent to adapt to climate change conditions, and will contribute to food security. Further evaluation of current varieties in different environments is necessary for more precise selection and will be useful for crop modeling.

Acknowledgments

I would also like to extend my thanks to Rebecca J. McGee, Ph.D., Research Geneticist, Grain Legume Genetics and Physiology Research, USDA – ARS, Washington State University, Pullman, Washington 99164 for providing guidance on editing this manuscript.

Funding Sources

This work was financially supported by National Agricultural Technology Program, NATP-Phase II, PIU, BARC, Project ID:20 and Bangladesh Agricultural Research Institute, Ministry of Agriculture, Bangladesh.

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