Doi: http://doi.org/10.5281/zenodo.3940411
Journal of Agricultural Science & Engineering Innovation (JASEI)
Vol. 01, No. 01, 2020

Varietal evaluation and selection of yield-associated traits of Potato (*Solanum tuberosum*) using correlation and path analysis in haor area of Moulvibazar, Bangladesh

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***Abstract*— The experiment was conducted with five high yielding varieties (HYVs) Potato BARI Alu-25, BARI Alu-35, BARI Alu-36, BARI Alu-37, BARI Alu-41 and one local potato variety as check at farmers field of haor area of Moulvibazar during the winter season of 2016-17. The number of tubers per plant was highest in local (48.33) and lowest in BARI Alu-25 (10.16).). The highest yield per hectare (26.98 t and 26.88 t) were also observed in BARI Alu-35 and BARI Alu-37, respectively while the local variety produced the lowest yield per hectare (14.43 t). The correlation and path analysis revealed that the number of leaves per plant and tuber yield per plant had a highly significant positive interrelationship (r = 0.94) with tuber yield per hectare. Again, days to harvest and individual tuber weight also exerted a highly significant positive correlation (r = 0.98) with tuber size. The number of leaves per plant, individual tuber weight, and days for harvest exhibited maximum positive direct effect (4.17, 3.76 and 3.13, respectively) on tuber yield per hectare. So these traits should be given preference for potato improvement in haor areas of Bangladesh.**

Keywords*— *Potato; evaluation; correlation; path analysis; tuber yield

I. INTRODUCTION

Potato (Solanum tuberosum L.) is one of the most important vegetables and food crops [1, 2] which center of origin is in the Andes [3] and it is the fourth highest produced crop worldwide after wheat, corn and rice [4]. Potato is currently cultivated in over 149 countries and is a rich source of carbohydrates and provides other essential nutrients, such as dietary fiber, vitamins, minerals, protein, and antioxidants [5]. Potatoes feed more than a billion people worldwide, from a global crop production close to 400 million metric tons [4] and it is critical for the food and nutritional security of people across the globe. Potato cultivation area has replaced all other food crops in developing countries from the early 1960s, which account for more than half of global potato production in these regions [6].

Environmental stresses are very common phenomena in haor areas of Bangladesh where waterlogging and flooding, hail storm are very common during May to November and water scarcity and drought from January to April which limiting the crop production. Haor is the depressed basin like typical low land area mainly with one cropping season i.e. the Rabi where almost 80% of the area is covered by Boro rice, while only about 10% area is covered by T. Aman production and also some extent B. Aus and hybrid rice [7, 8]. But a considerable land area remain fellow during Rabi due to water limitations and drought [9]. Due to climate change, this area is gradually increasing in different locations of haor districts [10]. Moreover, yield has a low heritability and greatly influenced by genotype × environment interactions [11]. So it is indeed imperative to exploit the existing cropping pattern production potentiality of the large haor areas with diversed crops with wide adatability [12,13]. Some farmers grow local potato varieties on the medium highland of haor area. But there is a high demand of HYV potato seeds and local potato varieties can be replaced by new BARI HYV potatoes. [9].

Tuber yield is a complex character associated with many interrelated components. The study of correlation between different quantitative characters provides an idea of association that could be effectively utilized in selecting a better plant type in potato breeding programme. Genotypic and phenotypic correlation coefficients tell us the association between and among two or more characters. A significant association suggests that such characters could be improved simultaneously. [14, 15]. It is necessary to have a good knowledge of those characters that have significant association with yield because the characters can be used to direct selection criteria or indices to enhance performances of varieties in a new plant population. Correlation coefficient alone cannot give a complete scenario of the causal basis of relationship and that cases, path coefficient analysis is an effective instrument [15]. Path coefficient analysis shows the degree and extent of direct and indirect effects of the causal components on the response component [16, 17]. Considering the importance of potato on these aspects the present investigation was taken up to evaluate BARI HYV potatoes to identify suitable variety for improving the existing cropping system and cropping intensity and to study these genetic parameters which would be utilized for further improvement of potato for haor areas of Bangladesh.

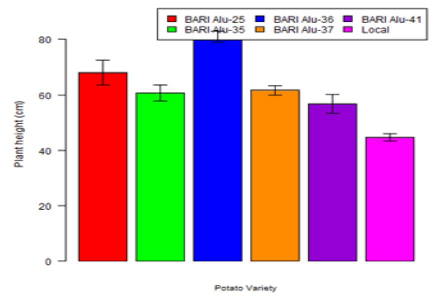
II. MATERIALS AND METHODS

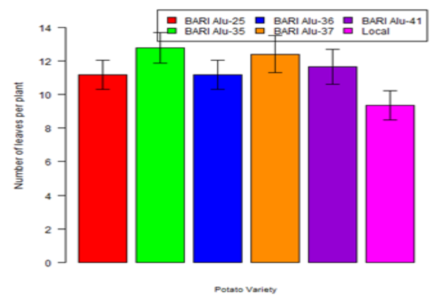
The experiment was conducted at farmers field of haor area of Gumra village of Moulvibazar sadar upazilla during the winter season of 2016-17. Five high yielding varieties (HYVs) of Potato: BARI Alu-25, BARI Alu-35, BARI Alu-36, BARI Alu-37, BARI Alu-41 were selected for this study and one local potato variety was used as a check. The experiment was laid out in randomized complete block design with 3 replications. The unit plot size was 8m × 5m. Seeds were sown on 01 December 2016 maintaining 60 cm × 25cm plant spacing. Manure and Fertilizers were applied @ 10 ton well decomposed cowdung, 115 kg N, 30 kg P and 125 kg K, 22 kg S, 3.5 kg Zn and 2.0 kg B per hectare. All fertilizers and half N were applied during land preparation. The remaining half of N was applied at 35 DAS at 2nd earthing up. Irrigation, intercultural operation and pest management were done as and when necessary. Plant height was measured on a metre scale for each genotype per plot from the ground level to the shoot apex of the plant and averaged. At full growth of the plant, number of leaves per plant were measured. Number of tubers per plant, tuber size and average weight of tuber were recorded at maturity. Days to harvest was measured when haulms (stems or stalks of potatoes) had died down naturally and tuber skin was hardened. Tuber yield was recorded at harvest of whole plot and converted to yield per hectare. Data were recorded on yield and yield contributing characters and subjected to analysis of variance following [18] Steel et al. (1997) analyzed statistically with STAR 2.0.1 software. The path and correlation analyses were conducted as described by Dewey and Lu (1959) and Snedecor and Cochran (1987) [19, 20], respectively, analyzed using R version 3.6.3 [21]. for correlation and path analysis with agricolae package [22].

III. RESULTS

The results on yield and yield contributing characters of Potato varieties are presented in Figure 1 and Table 1. Plant height was highest in BARI Alu-36 (81.0 cm) and lowest in Local (44.66cm). Local potato variety exhibited earlier period (76.33 days) to 1st harvest while BARI Alu-36 was late (89.66 days). Number of leaves per plant was highest (12.77) in BARI Alu-35 and lowest (9.33) in local potato variety. Number of tubers per plant was highest in local (48.33) and lowest in BARI Alu-25 (10.16). BARI Alu-37 had the highest (5.56 cm) tuber length but local showed lowest (2.36) tuber length. BARI Alu-36 and BARI Alu-41 had the statistically same highest tuber breadth and local had the lowest (2.40) value. Highest individual tuber weight was found in BARI Alu-36 (22.83 g) and the lowest was obtained from the local (6.95g). BARI Alu-37 produced the highest tuber yield per plant (757.0 g) and the lowest tuber yield per plant obtained from the local (212.0g). The highest yield per hectare (26.98 t and 26.88 t) were also observed in BARI Alu-35 and BARI Alu-37, respectively while the local variety produced the lowest yield per hectare (14.43 t). Diseases infestation in tubers was highest in BARI Alu-41 (15.89%) and lowest (1.0%) in the local. Insect infestation in tubers was highest in BARI Alu-35(2.17%) and lowest (0.11%) in the the local potato variety. Farmers reaction were very good for BARI Alu-35 and BARI Alu-37 for higher tuber yield and quality.

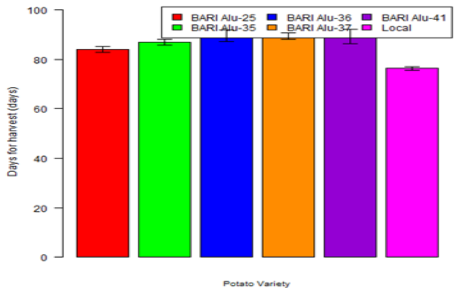
Tuber yield is a complex trait which is dependent on other contributing characters and also existing climatic factors. All of the HYV BARI varieties performed better than the locally adopted variety. But the local variety exhibited higher diseases and insect resistance due to their adaptance and genetic resistance properties. In haor ecosystem other researcher also found similar trends of tuber yield in potato. [23]. The cause of lower tuber production in stressed climate is also described by other researchers [24]. In water limiting environment similar tuber yield was also reported in Brazil [25, 26]. Regarding other yield contributing traits such as plant height, tuber weight and shape, number of tubers per plant also same result pattern in another study [27].

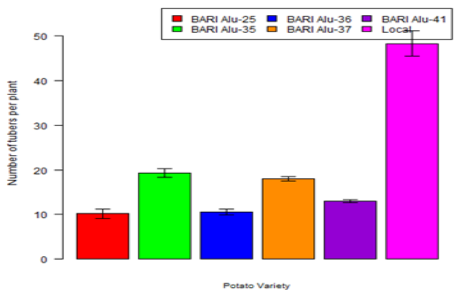


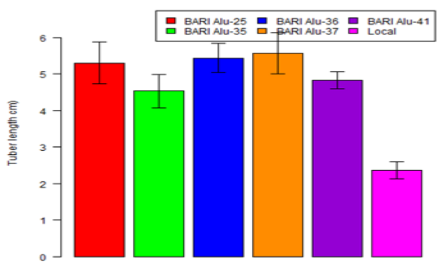


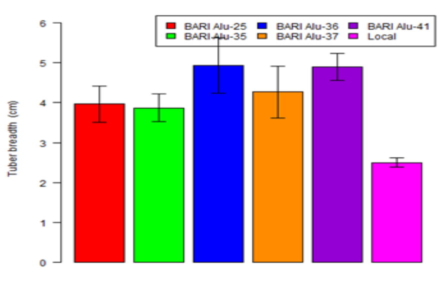
Global climate change has affected weather patterns resulting in extremes of environmental stresses [28]. The sub-optimal growth conditions associated with global warming and climate change negatively impact cop growth, survival and ultimately the yield [29]. Major abiotic stresses namely, high temperature, drought, soil salinity, waterlogging and nutrient stresses adversely affect these processes and substantially curtail plant growth, tuberization, tuber bulking, and hence tuber yield and quality [30, 31]. The nature and magnitude of yield loss due to these stresses depends on the duration, severity and crop growth stage [32]. Early growth stress is most detrimental to tuberization, bulking and tuber yield as due to reduced rates of carbon assimilation and ceased partitioning of assimilates to tubers [33].

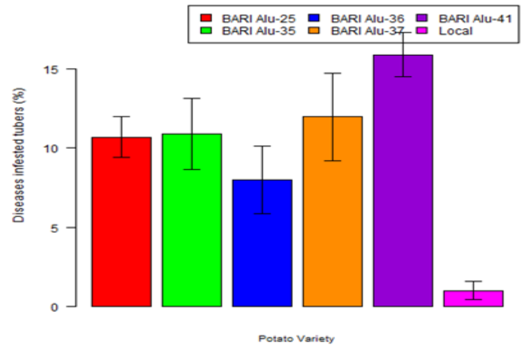
The combination of high humidity and/or high temperature may enable the existence of several other fungus such as, early blight caused by *Alternaria solani*, black dot caused by *Colletotrichum coccodes* and bacterial diseases such as *Pectobacterium chrysanthemi*, *Ralstonia solanacearum* especially important for quality seed production [34, 35].

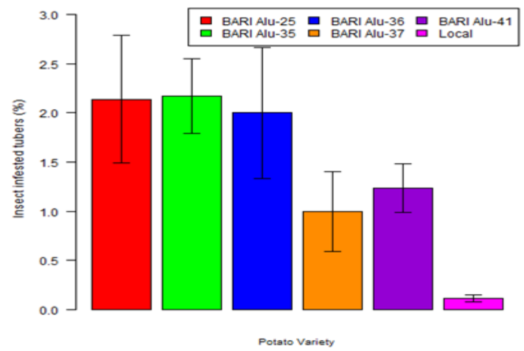


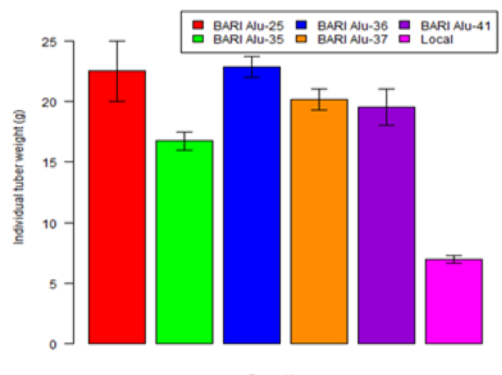


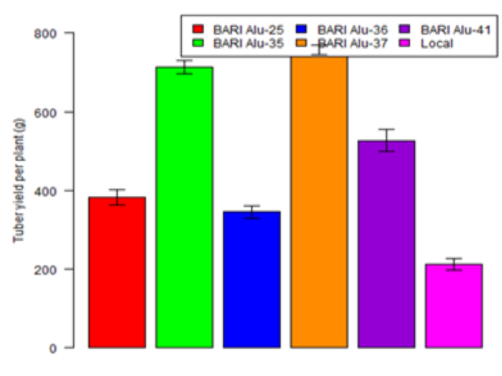


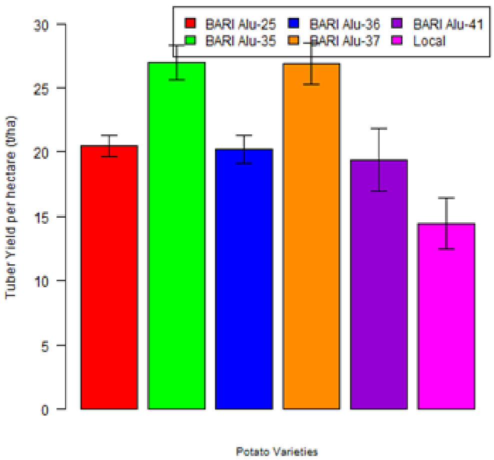












Again, changes in the rate and intensity of harsh climatic events will perturb ecosystems and increase their susceptibility to invasions through provision of new chances for dispersal and growth of insect species [36]. Long-term drought may also play role for reduced crop growth and health there by increasing their susceptibility to insect pests infestation and ultimately affects the yield [37].

Figure 1 Experimental field view of potato varieties at farmers field during 2016-2017

Table 1. Correlation co-efficient between 11 yield and yield contributing characters in potato genotypes

	NLF	DFH	NTPP	ITW	TL	TB	DIF	INIF	YPP	YPH
PH	0.4	0.73	-0.78	0.85*	0.78	0.76	0.28	0.76	0.13	0.36
NLF		0.8	-0.75	0.69	0.77	0.59	0.8	0.71	0.94**	0.94**
DFH			-0.99**	0.98**	0.98**	0.95**	0.85*	0.73	0.63	0.66
NTPP				-0.98**	-0.94**	-0.97**	-0.82*	-0.79	-0.54	-0.58
ITW					0.98**	0.96**	0.73	0.72	0.49	0.56
TL						0.9	0.75	0.67	0.63	0.69
TB							0.79	0.66	0.37	0.39
DIF								0.5	0.73	0.58
INIF									0.44	0.61
YPP										0.94**

df = 6-2 = 4; r0.05 = 0.812, r0.01 = 0.917, ** Significant at 1% level * Significant at 5% level.

PH= Plant height at harvest (cm), NLF= Number of leaves per plant, DFH= Days for harvest (days), NTPP= Number of tubers per plant, ITW= Individual tuber weight (g), TL= Tuber length (cm), TB= Tuber breadth (cm), DIF= Diseases infested tubers(%), INIF= Insect infested tubers(%), YPP=Tuber yield per plant (g.), YPH= Yield (t/ha).

Correlation coefficient analysis measures the extents of relationships between various plant traits and can aid the detection of component traits which can be selected for increased yield. Correlations of morphological and biochemical traits with yield in potato have been reported by several researchers [38, 39, 40,41]. In present study (table 1), plant height at harvest had significant positive correlation (0.85) with tuber length and non-significant positive correlation with all other traits except number of tubers per plant. Number of leaves per plant highly significant positive correlation (0.94) with tuber yield per plant and Yield per hectare and non-significant positive relationship with all other traits but with number of tubers per plant non- significant negative relationship. Days for harvest showed highly significant positive relationships with individual tuber weight (0.98), tuber length (0.98), tuber breadth (0.95) and significant positive relationship (0.85) with diseases infested tubers. Again highly significant negative relationship (0.99) with number of tubers per plant. Number of tubers per plant exhibited highly significant negative correlation with individual tuber weight (-0.98), tuber length (-0.94), tuber breadth (-0.97) but significant negative correlation (-0.82) with diseases infested tubers. Individual tuber weight showed highly significant positive correlation with tuber length (0.98) and tuber breadth (0.96). Yield per plant exhibited highly significant positive correlation (0.94) with tuber yield ton per hectare.

Similar stronger positive correlations between tuber yield and main stems/plant, plant tuber weight, plant height were found in potato [42]. In another study total tuber yield per plot exhibited highly significant and positive relationships with marketable yield per plot, number of tubers per plant, dry matter and number of stems [43]. Tuber yield was in positive correlation with number of tubers per plant, number of stems per plant, number of leaves per plant and tuber weight. Furthermore, tuber yield exhibited a significant negative correlation with days to maturity [44].Plant vigour, number of compound leaves per plant and number of tubers per plant, average weight of a tuber and dry matter content of tuber had high degree of positive association with tuber yield per plant [45]. Highly significant correlation between yield and yield per plant, individual fruit weight and fruit breath were observed in tomato by other researcher also. [46].

Path co-efficient analysis (Table 2) estimate the direct and indirect effects on yield and its 11 component characters. Number of leaves exerted highest (4.17) positive direct effect on yield per hectare, followed by individual tuber weight (3.76), days for harvest (3.013). Negative direct effect on yield observed for yield per plant (-3.25) plant height (-2.085), tuber breadth (-2.81), diseases infested tubers (-2.15) and number of tuber per plant (-0.72), respectively. Plant height showed maximum positive indirect effect via individual tuber weight (3.19) followed by days for harvest (2.28), number of leaves (1.67) and yield per hectare. Again, plant height showed highest negative indirect effect via tuber breadth (-2.13) followed by diseases (-0.6), tuber length (-0.56), insect (-0.37) infested tubers and yield per plant (-0.42).

Number of leaves exhibited maximum positive indirect effect through individual tuber weight (2.59) followed by days for harvest (2.50), yield (0.94) and number of tubers per plant (0.15) and maximum negative indirect effect through yield per plant (-3.06) followed by diseases infested tubers (-1.72), tuber breadth (-1.66) and plant height (-1.14). Days for harvest showed highest indirect positive effect via individual tuber weight (3.68), number of leaves (3.33) and maximum negative indirect effect through tuber breadth (-2.67), plant height (-2.08), yield per plant (-2.05) and diseases infested tuber (-1.83). Number of tuber per plant showed maximum direct positive effect through tuber breadth (2.72) followed by plant height (2.22), diseased infested tubers (1.76) and yield per plant (1.76) but negative effect via individual tuber weight (-3.68) followed by number of leaves per plant (-3.13), days for harvest (-3.10). Individual tuber weight exerted maximum indirect positive effect through days for harvest (3.07) followed by number of leave per plant (2.88) and yield (0.56) but maximum negative indirect effect for tuber breadth (-2.69), plant height (-2.42), yield per plant (-1.59), diseases infested tubers (-157). Tuber length showed maximum indirect positive effect via individual tuber weight (3.68), followed by number of leaves (3.21), days for harvest (3.07) but maximum negative indirect effect for tuber breadth (-2.52) followed by plant height (-2.22), yield per plant (-2.05), disease infested tubers (-1.61). Tuber breadth exhibited highest indirect positive effect through individual tuber weight (3.61) followed by days for harvest (2.97), number of leaves (2.46) but negative effect for plant height (-2.17), disease infested tubers (-1.70), yield per plant (-1.2).

Disease infested tuber exerted highest indirect positive effect via number of leaves per plant (3.33) followed by individual tuber weight (2.74), days for harvest (2.66) but maximum negative indirect effect through yield per plant (-2.38) followed by tuber breadth (-2.22), plant height (-0.80). Insect infested tubers showed maximum indirect positive effect via number of leaves per plant (2.96) followed by individual tuber weight (2.70), days for harvest (2.28) but negative indirect effect for plant height (-2.17), tuber breadth (-1.85), yield per plant (-1.43) and disease infested tubers (-1.07). Yield per plant exhibited highest indirect positive effect via number of leaves per plant (3.92) followed by days for harvest (1.97), individual tuber weight (1.84) but negative indirect effect for disease infested tuber (-1.57), tuber breadth (-1.04) and plant height (0.37).

The path coefficient analysis developed by Wright [47, 48] and applied by Dewey and Lu [19] with a standardized partial regression analysis that can be useful in separating the correlations into direct and indirect effects. It has been widely utilized by researchers to assess the importance of yield components [49, 50] and to reveal direct or indirect interrelations between morphological parameters in different crops [51-54, 46].Path analysis showed that the traits related to yield, number of tubers per plant and tuber weight, had high positive direct effects on tuber yield. Furthermore, tuber weight had an indirect negative effect on tuber yield through the number of tubers. Tuber size had a low correlation with tuber yield because a positive indirect effect through tuber weight was balanced by a negative indirect effect through tuber number. The number of stems and number of leaves had positive indirect effects on tuber yield through tuber numbers, whereas days to maturity had a negative indirect effect through tuber numbers. [44, 45]. Here we found different results for tuber size and days to maturity in comparison to our study [44, 45].

In another study, path analysis of tuber yield and its traits demonstrated that plant height, medium tuber weight and big tuber weight evolved the highest direct influence, respectively [42].Number of tubers per plot and plant height showed positive correlations with maximum direct effect on yield and these characters were least influenced by environment which also supports our result [27].Another researcher found that numbers of tubers per plant, marketable yield per plot, number of stems at 60 DAP and tuber weight were the most influencing factors to improve the tuber yield in potato[43].

The residual effect (R) of path analysis was 0.129 which indicated that the character under the study contributed to 87.1 % of the tuber yield of the studied potato varieties per hectare. It also indicated that there were some other factors which contributed 12.9 % to the tuber yield per hectare which were not studied in this experiment such as environmental factors and sampling errors. [57].

Table 02. Genotypic path coefficient analysis showing direct (diagonal bold) and indirect (non-diagonal) effect of 11 characters on yield of potato

	PH	NLF	DFH	NTPP	ITW	TL	TB	DIF	INIF	YPP	YPH
PH	**-2.85**	1.67	2.28	0.16	3.19	-0.56	-2.13	-0.60	-0.37	-0.42	0.36
NLF	-1.14	**4.17**	2.50	0.15	2.59	-0.55	-1.66	-1.72	-0.35	-3.06	0.94
DFH	-2.08	3.33	**3.13**	0.20	3.68	-0.70	-2.67	-1.83	-0.36	-2.05	0.66
NTPP	2.22	-3.13	-3.10	**-0.20**	-3.68	0.67	2.72	1.76	0.39	1.76	-0.58
ITW	-2.42	2.88	3.07	0.20	**3.76**	-0.70	-2.69	-1.57	-0.35	-1.59	0.56
TL	-2.22	3.21	3.07	0.19	3.68	**-0.72**	-2.52	-1.61	-0.33	-2.05	0.69
TB	-2.17	2.46	2.97	0.20	3.61	-0.64	**-2.81**	-1.70	-0.33	-1.20	0.39
DIF	-0.80	3.33	2.66	0.17	2.74	-0.54	-2.22	**-2.15**	-0.25	-2.38	0.58
INF	-2.17	2.96	2.28	0.16	2.70	-0.48	-1.85	-1.07	**-0.49**	-1.43	0.61
YPP	-0.37	3.92	1.97	0.11	1.84	-0.45	-1.04	-1.57	-0.22	**-3.25**	0.94

Residual effect= 0.129

PH= Plant height at harvest (cm), NLF= Number of leaves per plant, DFH= Days for harvest (days), NTPP= Number of tubers per plant, ITW= Individual tuber weight (g), TL= Tuber length (cm), TB= Tuber breadth (cm), DIF= Diseases infested tubers (%), INIF= Insect infested tubers(%), YPP=Tuber yield per plant (g.), YPH= Yield (t/ha).

Conclusion

Considering yield and yield contributing traits BARI Alu-35 and BARI Alu-37 performed better in haor area of Moulvibazar and farmers are highly satisfied with their yields. For improving potato for haor areas the traits; yield per plant, number of leaves per plant, tuber size, days for harvest should be given preferences. Moreover, more multi-locational trials with more high yielding potato varieties should be conducted for more precise results.

Acknowledgment

The authors are thankful to the Bangladesh Agricultural Research Institute (BARI) and Regional Agricultural Research Station (RARS), Akbarpur, Moulvibazar, Research and Field staff for financial and infrastructural support and cooperation to conduct this experiment.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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