



Associations among yield and yield contributing traits of potato (*Solanum tuberosum*) in north-western plains of India

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Potato (*Solanum tuberosum* L.) is a critical crop in terms of food security in the face of population growth and increased hunger rates. Potato crop improvement programmes are focused on increasing its productivity in face of stagnating cropping areas. However, yield being a polygenic trait cannot be directly selected, but selection can be based on its component characters (Luthra 2001), there by making it pertinent to study the association among the various characters affecting yield in the specific environment of interest. The present research was aimed at evaluating the tuber yield components and their inter-relationships by path analysis (Wright 1921, Dewey and Lu 1959) for their utility in potato breeding programme in North-Western plains of India under early (75 days harvested) irrigated conditions. The dependent character total yield in the present study was further partitioned into yield of undersized and marketable tubers based on the desirable and undesirable parts of total yield respectively. Total and marketable yield per plant, are selected for, whereas undersize tubers yield may be selected against in a breeding programme unless breeding for baby potatoes or similar objective. Classification of tuber grades for establishing relationships among characters has also been reported by Arslan (2007), Khayatnezad *et al.* (2011) and Muhinyuza *et al.* (2015).

The experiment was carried out during *rabi* 2013-14 in the north-western plains of India in the *Doaba* region of Punjab under early (75 days harvested) rainfed-irrigated conditions comprising 183 advance generation clones of third clonal generation derived from *Tuberosum* × *Tuberosum* crosses with 3 controls namely, Kufri Khyati, Kufri Pukhraj and J.95-227 (an advanced high yielding clone), planted in an augmented design (design generated using IASRI design resources server <http://www.iasri.res.in/design/Augmented%20Designs/home.html>). It comprised of 5 blocks of 43 entries each except 5th block comprising

of 41 entries, each control repeated twice in each block, providing a total of 213 genotypes in the experiment for evaluation of the association. Seed-size tubers, were planted in a single 3 m row with 60 cm row to row distance and standard agronomic practices were followed for the potato crop. Agronomic characters namely plant height (PH), number of stems/plant (NS), number of leaves/stem (NL), leaf angle (LA) and tuber characters namely number of tubers/plant (NT), number of marketable tubers/plant (NMT), number of undersized tubers/plant (NUT), average yield of tubers/plant (YT), average marketable yield/plant (YMT) and average undersize yield/plant (YUT), were recorded at 45 days after planting and tuber characters after 75 days haulm cutting and subsequent harvest after due skin curing. All characters were worked out on per plant basis, in order to retain uniformity for comparisons. While grading, the tuber of sizes less than 25 gm (<30 mm) were designated as undersize and more than 25 gm (>30 mm) as marketable tubers. Sigma Plot 12.0 was used to derive simple correlation among characters and Path coefficient was calculated using procedure PROC IML of SAS, where tuber yield (YT), average marketable tuber yield (YMT) and average undersize tuber yield (YUT) were considered to be the dependent variables (effect) while the other 7 characters, were considered as independent variables (causes) contributing directly or indirectly to the yield. Residual effects and coefficient of determination were worked out (Kang 2015).

The distribution characteristics depicted considerable variation with coefficient of variation above 20% in all characters except leaf angle (LA) and number of leaves (NL) showing CV of 3.53 and 12.75% each offering ample scope of selection. Highest coefficients of variation were observed for number (NUT) and yield of undersize tubers (YUT) 60.93 and 57.74 offering scope of selection against the specific trait in the population. Similar observation was also reported by Khayatnezad *et al.* (2011) and Burhan (2007).

The significant and important correlations established in the present study have been tabulated in Table 1. These include positive correlation (0.99) between total tuber yield (YT) and marketable yields (YMT), and a significant yet

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Table 1 Correlation coefficients among different characters in potato

Character pair	Correlation coefficient	Character pair	Correlation coefficient
YT YMT	0.99**	YUT NS	0.24**
YT YUT	0.22**	NMT NUT	0.40**
YT NT	0.41**	NT NMT	0.82**
YT NMT	0.53**	NT NUT	0.85**
YT PH	-0.14*	NUT PH	-0.19**
YT NUT	0.16*	NUT NS	0.26**
YMT NMT	0.49**	NMT NS	0.16*
YMT NT	0.31**	PH NT	-0.16*
YUT NUT	0.78**	PH NL	0.49**
YUT NT	0.67**	NS NL	-0.16*
YUT PH	-0.25*	NS NT	0.25**

*, **Significant at $P \leq 0.05$ and 0.01 , respectively

lower correlation of 0.22 between YT and YUT. This is as expected and indicative of marketable yield forming the major component of total yield. Similarly, total number of tubers/plant (NT), showed significant and higher correlation of 0.82 and 0.85 with NMT and NUT. The number of tubers was significantly associated with yield of tubers in each respective grade, showing different magnitudes of correlation, viz. 0.78, 0.49 and 0.41 for undersize, marketable and total tuber numbers and their yields respectively. The correlation between NUT and YT though significant was of very low magnitude (0.16) as compared to significantly higher correlation established between NMT and YT (0.53). Strong positive and significant correlation between average tuber yield/plant (YT) and tuber number/plant had also been reported by Rajkumar and Kang (2000), Luthra (2001), Luthra *et al.* (2005), Galarreta *et al.* (2006), Kamal *et al.* (2007), Ummyiah *et al.* (2013) and Muhinyuza *et al.* (2015). The highly significant yet average correlation between NMT and NUT (0.40), indicate scope of selection in favour of NMT and against NUT.

While comparing morphological characters, low negative but significant correlation of Plant height (PH) with NT, NUT and YT having magnitudes -0.16, -0.19 and -0.14 was observed. It can therefore be understood that in breeding potato for higher yield, dwarf plants may yield higher than tall potato plants. Arslan, (2007), Burhan, (2007), Yildirium *et al.* (1995), Ummyiah *et al.* (2013), Luthra *et al.* (2005), Luthra (2001) reported strong positive correlation between tuber yield and plant height contradictory to the present findings probably due to early conditions considered in the present experiment. Simultaneously, plant height was also found to be quite significantly positively correlated (0.49) with number of leaves, which is also expected with longer shoots having more number of leaves per plant (NL). A highly significant but weak correlation of NS with total as well as graded undersize and marketable tubers (0.25, 0.26 and 0.16) indicates role of genotypic partitioning of total

photosynthetic solutes between source and sink. Positive significant correlation between plant height and mean stems/plant had been reported by Arslan (2007).

Morphological characters besides these did not show much significant correlations with any of the characters except between NS and NL (-0.16). Positive association of number of stems having low correlation coefficients creates an unclear picture of association with yield/number of tubers which was also reported by Rajkumar and Kang (2000).

The results of path analysis depicted positive direct effect of NT on YT and YUT (0.381 and 0.232) but negative direct effect on YMT (-0.459). The major positive indirect effect was exerted through NMT (0.6898) in the latter case, which was in agreement to the correlation study offering a scope of selection of NMT for improving yield. Similar indirect effect of NMT (0.315) was also observed in effect of NT on YT. The indirect effects of NMT were in variably high and positive in effects of NUT on YT, YMT and YUT (0.159, 0.350, 0.289 respectively). The direct effects of NMT on YT and YMT were 0.382, 0.837 while it was negative for YUT (-0.137). On comparison of morphological characters, it was observed that PH and NS had negative direct effects on YT and YMT. Whereas NL and A exerted positive direct effects. For YUT, these effects were reciprocal except that it had small positive effect. The results of path analysis were able to further resolve the association relationships for yield attributes. Previous workers established positive association of plant height and number of stems per plant on yield (Gopal *et al.* 1994, Luthra *et al.* 2001, Luthra *et al.* 2005, Arslan 2007, Khatnezaad *et al.* 2011). However based on the present study it may be interpreted that shorter plant type with more number of leaves and wider leaf angles for intercepting more sunlight would be more higher yielding under early conditions of north-western plains of India.

With consideration of quite a large number of genotypes (213), the study indicated that genotypes with shorter plant type with more number of leaves and wider leaf angles would aid in indirectly selecting for higher tuber yield under early conditions, ensuring optimum partitioning of photosynthates. Total yield was strongly affected by yield of both undersize tubers and economically sized tubers. However, high CV of NUT and YUT, average correlation between NMT and NUT and also path analysis indicate feasibility of selecting lines with higher marketable tubers and lower undersize tubers, which may aid in selection towards increased yield. The highly significant associations and low magnitude, between character of interest may be suitably deployed by their incorporation into selection indices framed for specific breeding conditions, besides use of sequential path analysis, considering variance inflation factor (VIF) may be explored in future to eliminate collinearity and further refine the associations, in aid to selection.

SUMMARY

The study comprising 183 potato (*Solanum tuberosum* L.) genotypes planted in augmented design with three controls, viz. Kufri Khyati, Kufri Pukhraj and J 95-227 was

undertaken to study the association effects using simple correlation and path coefficient analysis of morphological and yield contributing characters on yield under early conditions of north-western plains. The total yield was partitioned into marketable and undersize tubers yield and direct and indirect effects were evaluated. The association study revealed that shorter plants, with larger number of leaves and wider leaf angles would be higher yielding under early conditions of north-west plains. Number of tubers was identified as the major contributor to yield. Correlation, path analysis and high CV for undersize tuber number and yield revealed scope of selecting genotypes with larger number of marketable tubers and lesser number of undersize tubers to increase overall yield.

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