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TRAIT ASSOCIATION STUDY IN POTATO (*Solanum tuberosum* L.) FOR PROCESSING PURPOSE UNDER TWO DIFFERENT HARVESTING PERIODS

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ABSTRACT
The present investigation was carried out to study correlation and path analysis using fourty diverse genotypes of potato collected from different eco-geographical area of the country. The genotypes were evaluated in Randomized Block Design (RBD) with three replications in two sets of harvest *i.e.* 90 days after planting (DAP) and 105 DAP for tuber yield and processing traits in potato. The analysis of correlation coefficients suggested that the magnitude of genotypic correlation was higher than the corresponding phenotypic correlation for all the traits. The total tuber yield per plant was highly significant and positively associated with plant height, leaf area, number of stems per hill, number of tubers per plant, total tuber yield per plant, processing grade tuber yield per plant, average tuber weight at both genotypic and phenotypic levels at both harvesting periods. Processing grade tuber yield per plant had positive correlation with processing traits *viz.,* tuber dry matter, reducing sugar and chip colour index. The path coefficient analysis revealed that high and positive direct effects were exerted by plant height, number of tubers per plant, tuber dry matter and chip color index on total tuber yield indicating their relative contribution to the total tuber yield per plant at both 90 and 105 days of harvests. Therefore, plant height, number of tubers per plant, tuber dry matter and chip color index should be considered in selection criterion for enhancing tuber yield per plant.

KEY WORDS: Processing grade tuber, processing purpose genotypes, Potato genotypes, Correlation and path analysis**.**

INTRODUCTION
Potato having diversified use as vegetable, processed food, livestock feed and raw material for many industrial product. It is one of the most popular vegetables, which is available throughout the year in vegetable market due to its long term storability. Now-a-day many dehydrated products like diced franules, baries, papad, biscuits, flour *etc*., while, fried snacks like chips, French fries *etc.* are prepared from potato. Potato is widely used as raw materials in starch extraction industries. Potato tuber contains about 75 to 80 per cent water, 16 to 20 per cent carbohydrates, 2.5 to 3.2 per cent crude protein, 1.2 to 2.2 per cent true protein, 0.8 to 1.2 per cent mineral, 0.1 to 0.2 per cent crude fat, 0.6 per cent crude fiber and vitamins like 'B' and 'C' (Swaminathan and Pushkarnath, 1962). All the cultivated varieties available in the country are not suitable for processing (Sukumaran and Verma, 1993). To determine the quality of the processed potato product, dry matter and reducing sugar content of potato tuber are the two important parameters (Verma, 1991). High level of reducing sugar results in dark colour of fried products. Thus, the potato required for processing need to have tuber dry matter in the range of 21 to 23 per cent and reducing sugars below 150 mg per 100 g fresh weight of tubers (Anonymous, 2016). The processing varieties should also have reasonably good yield to provide economic returns to the farmers. Information on the nature and magnitude of variability present in the population is a prerequisite for initiating any systematic breeding programme. In any breeding programme, yield is major objective of a plant breeder, but yield is the complex and polygenic character which is highly influence by environment. Therefore, it is essential to know the relationship between various traits that have direct and indirect effects on yield. The knowledge of association between characters under study, especially yield and it's contributing traits in segregating population is useful for selection. Estimates of heritability for different characters under study provide clear picture for amount of heritable variation presence in different traits. Moreover, heritability in broad sense with higher genetic advance is a reliable measure of the amount of genetic gain through selection (Johnson *et al*., 1955).

MATERIALS & METHODS
The experimental material for present study comprised 40 potato genotypes. The field experiment was conducted at Potato Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa in two sets of harvest *i.e.* 90 days after planting (DAP) and 105 DAP. The experimental material was laid out in Randomized Block Design (RBD) with three replications. The experimental material was planted in field during *rabi* 2016-17 in two sets *i.e.* 90 (H_1) and 105 (H_2) days harvest. Each genotype was represented by single row of 3.0 m length. The inter and intra row distances were 50 and 20 cm, respectively, which accommodated fifteen plants per plot of each genotype. All the recommended packag of practices were followed for successful raising of the crop (Patel *et al.,*

1986). The data were recorded from five randomly selected plants from each entry in each replication for plant height (cm), leaf area (cm^2), number of stems per hill, number of tubers per plant, total tuber yield per plant (g), processing grade tuber yield per plant (g), average tuber weight (g), tuber dry matter (%), chip colour index (1-10), reducing sugar (%) and total soluble solids (ºBrix). The mean of the data recorded were used for statistical analysis. Estimation of Correlation co-efficient as per Singh and Chaudhary (1985), while, path co-efficient analysis by wright (1921) and Dewey and Lu (1959) were carried out.

RESULTS &DISCUSSION

Selection of a character for its improvement may simultaneously lead to selection of the associated characters. Therefore, in plant breeding, it is essential to understand the inter-relationship among different characters so that improvement of the targeted character does not carry with it the non-targeted characters rather desirable characters could be simultaneously included which may lead to ultimate success on breeding programme. The correlation coefficients at genotypic level were in general higher than phenotypic correlation values. Higher genotypic correlations than phenotypic ones might be due to modifying or masking effect of environment in the expression of these characters under study as explained by Nandpuri *et al*., (1973). Total tuber yield per plant (Table 1) had highly significant and positive association with plant height (rg = 0.429 and rp = 0.343 in H_1, rg = 0.476 and rp = 0.333 in H_2), leaf area (rg = 0.342 in H_1 and rg = 0.261 in H_2), number of stems per hill (rg = 0.544 and rp = 0.360 in H_1, rg = 0.336 and rp = 0.236 in H_2 condition), number of tubers per plant (rg = 0.305 in H_1, rg = 0.347 in H_2 condition), processing grade tuber yield per plant (rg = 0.952 and rp = 0.745 in H_1, rg = 1.00 and rp = 0.734 in H_2), average tuber weight (rg = 0.541 and rp = 0.473 in H_1, rg = 0.342 and rp = 0.410 in H_2) and reducing sugar (rg = 0.304 in H_2). The results accordance with these reported earlier by Verma and Singh (2015) and Tripura *et al.* (2016). Tuber dry matter (rg = -0.016 and rp = - 0.028 in H_1) had negative correlation with total tuber yield per plant for 90 days harvest and positive association at 105 days harvest (rg = 0.076 and rp = 0.130 in H_2). Datta *et al*. (2014) were also found non-significant but, negative correlation between total tuber yield per plant and tuber dry matter. Average tuber weight (r_g = -0.653 and r_p = -0.573 in H_1, r_g = -0.725 and r_p = -0.639 in H_2 condition) and chip colour index (r_g = -0.328 and r_p = -0.281 in H_1, r_g = -0.312 and r_p = -0.289 in H_2 condition) had highly significant and negative association with number of tubers per plant. Verma and Singh (2015) noticed significant but, negative correlation of number of tubers per plant with average tuber weight. The average tuber weight was positive and highly significantly associated with chip colour index (r_g = 0.429 and r_p = 0.313 in H_1, r_g = 0.443, r_p = 0.321 in H_2 condition), reducing sugar (r_g = 0.419 and r_p = 0.265 in H_1, r_g = 0.428 and r_p = 0.288 in H_2 condition), total soluble solids (r_g = 0.934 in H_1 condition) and total tuber yield per plant (r_g = 0.541 and r_p = 0.473 in H_1, r_g = 0.342 and r_p = 0.410 in H_2). Datta *et al*. (2014) were also obtained significant and positive correlation of average tuber weight with total tuber yield. Processing grade tuber yield per plant had positive correlation with processing traits *viz.*, tuber dry matter, reducing sugar and chip colour index suggesting that genotypes exerted lower processing grade tuber yield per plant had lower reducing sugar as well as lower chip colour index which is most suitable for processing purpose in potato. So in future in processing breeding programme, the genotypes having low reducing sugar as well as low chip colour index were desirable.

The path coefficient analysis (Table 2 and Fig 1a&b) revealed that plant height (0.094 and 0.044), number of tubers per plant (1.588 and 0.011), tuber dry matter (0.091 and 0.008) and chip color index (0.250 and 0.102) showed positive direct effects under both harvesting periods, respectively indicating their relative contribution to the total tuber yield per plant. Similar results were found by Pandey *et al.* (2005), Tuncturk and Ciftci (2005), and Verma and Singh (2015). Number of stems per hill (0.144) and average tuber weight (1.899) at 90 days of harvest, whereas, leaf area (0.102), processing grade tuber yield per plant (1.183) and total soluble solids (0.053) had at 105 days of harvest had positive direct effects on total tuber yield per plant. The direct positive effect of processing grade tuber yield per plant on total tuber yield per plant was incurred by Pandey *et al.* (2005). Highly Significant and positive genotypic correlation between leaf area and tuber yield per plant was observed by Ummyiah *et al.* (2013). The number of stems per hill had positive and highly significant direct effect on total tuber yield was reported by Datta *et al.* (2014). Number of tubers per plant exhibited high and negative indirect effects *via* average tuber weight (-1.036 in H_1), chip colour index (-0.521 in H_1) and reducing sugar (-0.359 in H_2) on total tuber yield. Similar result was reported by Bhagowati *et al*. (2003). Average tuber weight had high and negative indirect effects *via* number of tubers per plant (-1.239), number of stems per hill (-0.392) and tuber dry matter (-0.315) on total tuber yield per plant in H_1 period. The average tuber weight exhibited negative indirect effects *via* number of tubers per plant on total tuber yield per plant was revealed by Bhagowati *et al.* (2003). Chip colour index showed low and negative indirect effects *via* plant height (-0.086 and -0.037), leaf area (-0.006 and -0.010), number of stems per hill (-0.082 and -0.037), number of tubers per plant (-0.082 and -0.032), tuber dry matter (-0.082 and -0.028) and total soluble solids (-0.005 and -0.001) on total tuber yield under both H_1 and H_2 conditions, respectively.

TABLE 1: Genotypic and phenotypic correlations among different characters in potato

Characters		LA		NSH		NTP		PGY		ATW		TDM		CCI		RS		TSS		TTY	
		H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2
PH	r_g	0.029	0.117	0.407**	0.375**	0.318**	0.242**	0.461**	0.380**	0.022	-0.065	-0.112	-0.171	-0.342**	-0.360**	-0.322**	-0.291**	0.352**	0.322**	0.429**	0.476**
	r_p	0.027	0.084	0.319**	0.283**	0.245**	0.187*	0.411**	0.266**	0.046	0.015	-0.090	-0.095	-0.289**	-0.267**	-0.247**	-0.197*	0.275**	0.244**	0.343**	0.333**
LA	r_g			0.206*	0.403**	0.285**	0.230*	0.156	0.176	0.058	-0.087	-0.172	-0.140	-0.022	-0.095	0.026	0.089	-0.024	-0.183*	0.342**	0.261**
	r_p			0.165	0.308**	0.212*	0.184*	0.117	0.123	0.075	-0.080	-0.130	-0.083	-0.021	-0.081	0.003	0.068	-0.190*	-0.148	0.227*	0.141
NSH	r_g					0.609**	0.431**	0.412**	0.291**	-0.206*	-0.330**	0.048	0.143	-0.329**	-0.363**	-0.260**	-0.213*	0.629**	-0.005	0.544**	0.336**
	r_p					0.463**	0.359**	0.327**	0.227*	-0.128	-0.177	0.074	0.133	-0.272**	-0.318**	-0.220*	-0.163	0.038	0.006	0.360**	0.236**
NTP	r_g							0.156	0.141	-0.653**	-0.725**	0.071	0.074	-0.328**	-0.312**	-0.226*	-0.196*	0.122	0.055	0.305**	0.347**
	r_p							0.121	0.121	-0.573**	-0.639**	0.084	0.079	-0.281**	-0.289**	-0.164	-0.167	0.103	0.048	0.225*	0.218*
PGY	r_g									0.562**	0.498**	0.013	0.109	0.073	0.170	0.134	0.331**	0.104	0.109	0.952**	1.00**
	r_p									0.457**	0.320**	0.023	0.089	0.060	0.149	0.121	0.294**	0.089	0.094	0.745**	0.734**
ATW	r_g											-0.166	-0.068	0.429**	0.443**	0.419**	0.428**	0.934**	0.022	0.541**	0.342**
	r_p											-0.122	-0.005	0.313**	0.321**	0.265**	0.288**	0.078	0.039	0.473**	0.410**
TDM	r_g													-0.327**	-0.271**	-0.311**	-0.208*	-0.158	-0.194*	-0.016	0.076
	r_p													-0.315**	-0.253**	-0.287**	-0.193*	-0.146	-0.177	-0.028	0.130
CCI	r_g															0.896**	0.838**	-0.019	-0.011	0.127	0.139
	r_p															0.868**	0.815**	-0.021	-0.010	0.104	0.094
RS	r_g																	-0.041	-0.041	0.195*	0.304**
	r_p																	-0.038	-0.038	0.154	0.216*
TTS	r_g																			0.141	0.176
	r_p																			0.118	0.151

*, ** Significant at 5 and 1% levels, respectively.

PH = Plant height, LA = Leaf area, NSH = Number of stems per hill, NTP = Number of tubers per plant, PGY = Processing grade tuber yield per plant (g), ATW = Average tuber weight (g), TDM = Tuber dry matter (%), CCI = Chip color index (1-10), RS = Reducing sugar (%), TSS = Total soluble solids (ºBrix), TTY = Total tuber yield per plant (g)

$\mathbf{H_1}$ = Harvest at 90 DAP, $\mathbf{H_2}$ = Harvest at 105 DAP.

TABLE 2 : Genotypic path coefficient analysis showing direct (diagonal and bold) and indirect effects of different characters on total tuber yield per plant in potato (H_1=Residual effect = 1.107 and H_2 =Residual effect = 1.125)

Characters	PH		LA		NSH		NTP		PGY		ATW	
	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2
PH	**0.094**	**0.044**	0.003	0.005	0.038	0.017	0.030	0.011	0.043	0.017	0.002	-0.003
LA	-0.007	0.012	**-0.230**	**0.102**	-0.047	0.041	-0.066	0.024	-0.036	0.018	-0.013	-0.009
NSH	0.059	-0.054	0.030	-0.058	**0.144**	**-0.144**	0.088	-0.062	0.059	-0.042	-0.030	0.047
NTP	0.505	0.003	0.453	0.003	0.967	0.005	**1.588**	**0.011**	0.248	0.002	-1.036	-0.008
PGY	-0.173	0.449	-0.059	0.208	-0.155	0.344	-0.059	0.167	**-0.376**	**1.183**	-0.211	0.590
ATW	0.041	0.019	0.109	0.025	-0.392	0.096	-1.239	0.212	1.066	-0.145	**1.899**	**-0.292**
TDM	-0.010	0.001	-0.016	0.001	0.004	-0.001	0.007	-0.001	0.001	-0.001	-0.015	0.001
CCL	-0.086	-0.037	-0.006	-0.010	-0.082	-0.037	-0.082	-0.032	0.018	0.017	0.107	0.045
RS	0.105	0.021	-0.008	-0.006	0.085	0.015	0.073	0.014	-0.044	-0.024	-0.136	-0.031
TSS	-0.099	0.017	0.066	-0.010	-0.018	0.000	-0.034	0.003	-0.029	0.006	-0.026	0.001

Characters	TDM		CCL		RS		TSS		TTY	
	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2
PH	-0.011	-0.008	-0.032	-0.016	-0.030	-0.013	0.033	0.014	0.429	0.476
LA	0.040	-0.014	0.005	-0.010	-0.006	0.009	0.054	-0.019	0.342	0.261
NSH	0.007	-0.021	-0.047	0.052	-0.038	0.031	0.009	0.001	0.544	0.336
NTP	0.113	0.001	-0.521	-0.004	-0.359	-0.002	0.193	0.001	0.305	0.347
PGY	-0.005	0.129	-0.027	0.201	-0.050	0.391	-0.039	0.129	0.952	1.031
ATW	-0.315	0.020	0.815	-0.129	0.795	-0.125	0.177	-0.006	0.541	0.342
TDM	**0.091**	**0.008**	-0.030	0.002	-0.028	0.002	-0.014	0.002	-0.016	0.076
CCL	-0.082	-0.028	**0.250**	**0.102**	0.224	0.085	-0.005	-0.001	0.127	0.139
RS	0.101	0.015	-0.291	-0.060	**-0.325**	**-0.071**	0.013	0.003	0.195	0.304
TSS	0.044	-0.010	0.005	-0.001	0.012	-0.002	**-0.281**	**0.053**	0.141	0.176

PH = Plant height, LA = Leaf area, NSH = Number of stems per hill, NTP = Number of tubers per plant, PGY = Processing grade tuber yield per plant (g), ATW = Average tuber weight (g), TDM = Tuber dry matter (%), CCI = Chip color index (1-10), RS = Reducing sugar (%), TSS = Total soluble solids (ºBrix), TTY = Total tuber yield per plant (g)

H_1 = Harvest at 90 DAP, **H_2** = Harvest at 105 DAP.

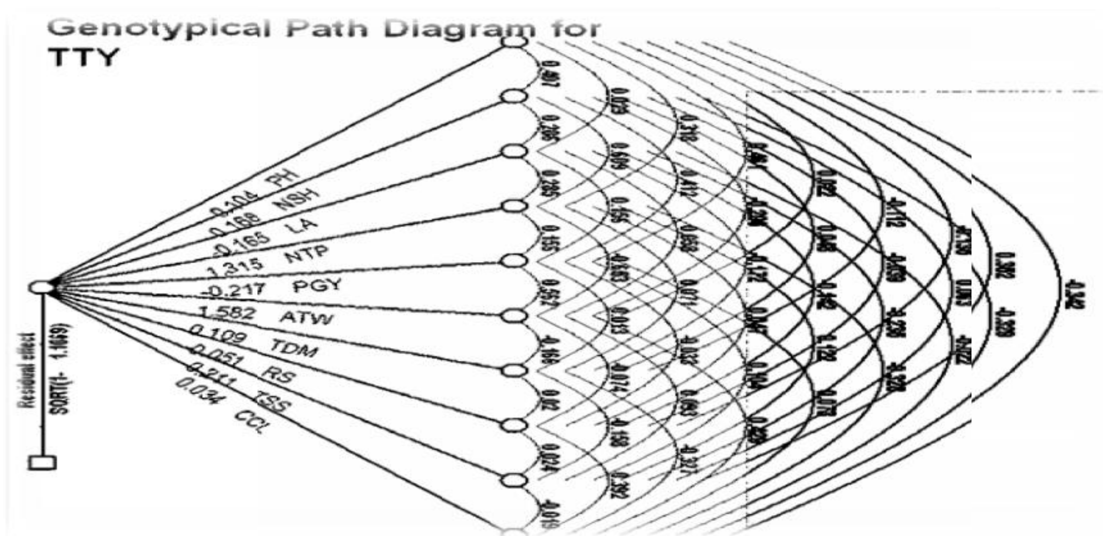

FIGURE 1a : Genotypic path diagram for total tuber yield per plant (g) at 90 days harvest

Where,

PH= Plant height (cm), LA= Leaf area (cm^2), NSH= Number of stems per hill (No.), NTP= Number of tubers per plant (No.), TTY= Total tuber yield per plant (g), PGY= Processing grade tuber yield per plant (g), ATW= Average tuber weight (g), TDM = Tuber dry matter (%), CCI= Chip color index (1-10), RS= Reducing sugar (%), TSS= Total soluble solids ($^\circ$Brix).

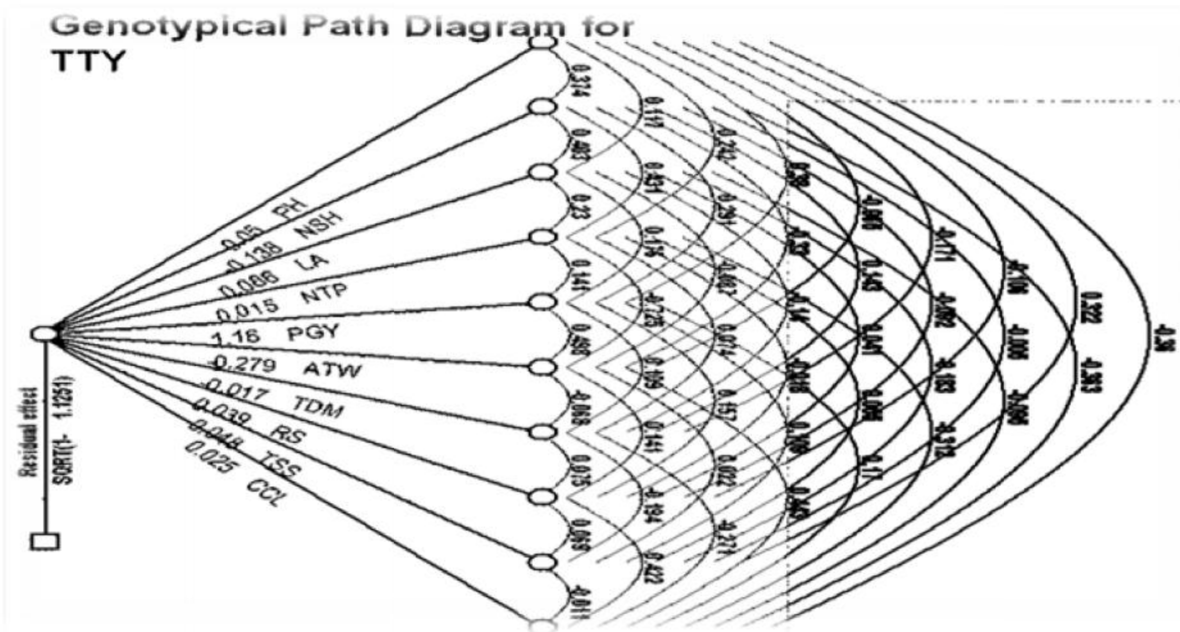

FIGURE 1b : Genotypic path diagram for total tuber yield per plant (g) at 105 days harvest

Where,

PH= Plant height (cm), LA= Leaf area (cm^2), NSH= Number of stems per hill (No.), NTP= Number of tubers per plant (No.), TTY= Total tuber yield per plant (g), PGY= Processing grade tuber yield per plant (g), ATW= Average tuber weight (g), TDM = Tuber dry matter (%), CCI= Chip color index (1-10), RS= Reducing sugar (%), TSS= Total soluble solids (°Brix)

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