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Yield Components of Potato [*Solanum tuberosum* (L.)] and Their Relationship with Tuber Yield

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ABSTRACT

Background: Tuber yield in potato is a function of positive association of tuber related traits. Understanding the interplays of these traits is useful for a meaningful selection process and tuber yield improvement.

Methods: Field experiment was conducted in 2017-18 and 2018-19 dry seasons at Teaching and Research Farm of Faculty of Agriculture, Bayero University, Kano and Teaching and Research Farm of Kano University of Science and Technology, Wudil to assess the relationships of yield related characters and their contribution to-tuber yield in potato. Treatments comprised of five planting times (late October, early November, mid-November, late November and early December), two methods of propagation (whole seed and cut seed) and three plant densities (66,666; 43,333 and 33,333) per hectare. These were combined and laid down in an incomplete-block design; in fractional factorial using D-optimality criterion. Simple and partial correlation analysis was carried out to determine the relationships, direct, indirect and combined contributions of the measured variables to tuber yield.

Result: Tuber yield, average tuber weight (g), number of tubers per plant and marketable tuber were positively correlated to tuber yield. Significant but negative correlation between number of non-marketable tubers and tuber yield was also observed. The direct, indirect and combined contributions of average tuber weight (g), number of tubers per plant, number of marketable and non-marketable tubers indicated significant improvement in tuber yield.

Key words: Contributions, Correlation, Cut seed, Potato, Tuber yield, Whole seed.

INTRODUCTION

Potato [*Solanum tuberosum* (L.)] is the edible tuber and a member of Solanaceae family. It is also called as earth apple, the potato is world's fourth largest food crop after wheat, rice and maize. China is the biggest producer of potato worldwide, with about one third of the world's potato produced in the China and India. According to FAO estimates, in 2019, over 370 million metric tons of potato were produced worldwide, a substantial increase from a production volume of 333.6 million tons in 2010.

Root and tuber crops have contributed significantly to staple food requirements in many developing countries, ensuring food security at national and household levels. The major roots and tuber crops used in Nigeria include: cassava (*Manihot esulenta*), yam (*Dioscorea spp*), sweet potato (*Ipomoea batatas*), coco yam (*Colocasia esculenta*) and Irish potato (*Solanum tuberosum*). Potato have been part of the regular feeding habit of many Nigerians. The crop is a major contributor to cross-substitution when other food items are in short supply (Ndor, 2013). Tuber yield in potato is a function of positive association of tuber related traits. Understand the interplays of these traits is useful for a meaningful selection process and tuber yield improvement (Sandhya Kiranmai *et al*., 2016).

In a study of some growth indices and their interrelationships with yield, number of leaves and plant height were reported to positively correlated to tuber yield (Kareem, 2014). Several authors have reported findings on relationships among important yield components and yield (Supriatna *et al.,* 2019; Sandhya Kiranmai *et al*., 2016). However, there were no adequate information on the character associations as well as percentage contributions of the various yield related components to tuber yield of potato in the study area. Therefore, this study was planned to assess the extent of relationships of the various yield related components andto evaluate their direct and indirect contributions to tuber yield of potato.

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MATERIALS AND METHODS

The experiment was conducted during 2017-18 and 2018-19 dry seasons at the Teaching and Research Farm of the Faculty of Agriculture, Bayero University, Kano (11°58′N and 8°25′E) andthe Teaching and Research Farm Kano University of Science and Technology, Wudil (11°25′N and 9°25′E) 400-430 m above sea level. The average temperature of the study areas was 26°C. These locations fall in the Sudan savanna agro-ecological zone of Nigeria.

Soil samples were collected from the experimental fields at 0-30 cm depths prior to planting. These were bulked and composite samples used to determine their physical and chemical properties (Table 1). The experiment involved a fractional factorial design of five (5) planting times (late October, early November, mid-November, late November and early December), two methods of propagation (whole seed and cut seed) and three plant densities [66,666 (20 cm), 43,333 (30 cm) and33,333 (40 cm)]. The design was generated using the design of experiment (DOE) platform of JMP 14 according to the D-optimality criterion (Atkinson and Donev, 1989).

Plot size was 3 $\times$ 4 m long consisting of four ridges. A distance of 1meter was maintained between plots and 1meter distance between blocks. The planting materials were sourced from National Root Crop Research Institute (NRCRI) sub station, Jos. Well sprouted tuber seed of potato var: Marabel was sown at a depth of 10 cm. First weeding was done manually using hand hoe at three weeks after planting andthe subsequent weeding were done when the need arose. NPK 15:15:15 was applied at the rate of 240kg/ha (Ugonna *et al.,* 2013).

Data collection and analysis

Data were collected on the average tuber weight, number of tubers per plant, tuber size, number of marketable tubers, number of non-marketable tubers and tuber yield. Simple correlation analysis was carried out to determine the relationships between the measured variables and the tuber yield. Simple correlation coefficients between the tuber yield (Y) and yield components (X) and within the yield characters themselves were worked out using the following equation after Poolman (1959).

$$Rxy = SPxy \sqrt{ssx.ssy}$$

Where,

Y = Correlation coefficient.

SPxy = Sum of products of x and y.

ssx = Sum of squares of x.

ssy = Sum of squares of y.

The calculated coefficients were further used to develop the following simultaneous equations in order to partition the correlations into cause and effect by working out the path coefficients (Pi).

$$r_{16} = p_1 + p_2 r_{12} + p_3 r_{13} + p_4 p_{14} + p_5 r_{15}$$
$$r_{26} = p_1 r_{12} + p_2 + p_3 r_{23} + p_4 r_{24} + p_5 r_{25}$$
$$r_{36} = p_1 r_{13} + p_2 r_{23} + p_3 + p_4 r_{34} + p_5 r_{35}$$
$$r_{46} = p_1 r_{14} + p_2 r_{24} + p_3 r_{34} + p_4 + p_5 r_{45}$$
$$r_{56} = p_1 r_{15} + p_2 r_{25} + p_3 r_{35} + p_4 r_{45} + p_5$$

From the above equations p_1, p_2, p_3, p_4 and p_5 are the path coefficients (direct effect) while p_1r_{13}, p_1r_{23}, p_1r_{34}, p_1r_{45}, p_2r_{23}, p_2r_{24}, p_2r_{25}, p_3r_{25}, p_3r_{34}, p_3r_{35} and p_4r_{45} are the indirect effects while r_{12} …… r_{56} are the correlation coefficients. The individual and combined percentage contributions of any two characters were also computed using the following relation as described by Gomez and Gomez (1984).

$$E = (p_i)^2 \times 100., \quad E_{ij} = 2 p_i p_j r_{ij} \times 100$$

Where,

E = Percent individual contribution.

E_{ij} = Combined percent contribution of characters i and j.

R_{ij} = Coefficient of correlation between i and j.

P_i and p_j = Path coefficients of characters i and j.

The residual factor (Rx), which represents the unaccounted error by the direct and combined effects, is calculated as: $Rx = 1 - (p_1r_{16} + p_2r_{26} + p_3r_{36} + p_4r_{46} + p_5r_{56})$, while the sum of the percent contribution (individual and combined) as well as the residual should add up to 100.

RESULTS AND DISCUSSION

The results of the soil analysis of the two experimental sites are presented in Table 1. The results showed that the soils at Wudil contains 59.81% sand, 21.32% silt and 18.84% clay. Therefore, soil texture was classified as sandy clay. The soil at BUK contains 64.20% of sand, 19.43% of silt and 16.37 of clay; hence, the soil texture was classified as clayey sand. It was observed that soil at Wudil was slightly acidic (6.41) and neutral (7.35) at BUK. The results also indicated that total nitrogen was high in both BUK and Wudil. The available phosphorus was medium (11.14) at Wudil and low (2.39) at BUK. Other significant differences in micronutrients of the soils of the two sites were observed especially Cu, Mn and Fe which were relatively higher at Wudil.

Simple correlation between yield components and tuber yield

Significant correlation was observed between yield components and tuber yield of potato (Table 2). The results

Table 1: Physical and chemical properties of soils of the experimental sites at 0-30 cm depths.

Soil properties	Wudil	BUK
Physical (%)		
Sand	59.81	64.20
Silt	21.35	19.43
Clay	18.84	16.37
classification	Sandy clay	Clayey sand
Chemical		
pH (1:1)	6.41	7.35
O C (%)	0.61	0.55
N (%)	0.09	0.07
P ($mgkg^{-1}$)	11.14	2.39
Mn ($mgkg^{-1}$)	11.74	3.72
Zinc ($mgkg^{-1}$)	1.86	7.48
Fe (mg/kg)	180.41	128.29
Exchangeable base (cmol (+) kg^{-1})		
Ca	1.39	1.14
Mg	0.34	0.51
K	0.08	0.07
Na	0.015	0.013
ECEC	1.82	1.73

Analyzed at Central Laboratory, Centre for Dry Land Agriculture Bayero University Kano.

from correlation analysis indicated a strong relationship between average tuber weight, number of tubers per stand, tuber size and number of marketable tubers to total tuber yield. Maity and Chatterjee (1997) also reported number of tubers per plant are closely connected with the yield of potato tubers. Similar observation was reported for strong positive correlation of number of roots per plant and root weight to root yield of sweet potato (Yahaya *et al*., 2015). However, a strong negative correlation exists between number of non-marketable tubers to all other yield component and tuber yield. All other yield components have positive correlation wiyh each other. This indicated that all these characters were important for tuber yield enhancement. Similar association was reported by Majid *et al.* (2011) and Lemma Tessema *et al.* (2020). However, a strong negative correlation exists between number of non-marketable tubers and tuber weight.

Direct, indirect and total contributions of some yield components to tuber yield

The direct, indirect and total contributions of yield components to tuber yield of potato is presented in Table 3. The total contribution of average tuber weight to tuber yield was significant (0.8910) while the direct contribution was (0.4082). This corroborates with the results of Yahaya *et al*. (2015) who reported root weight as the highest direct contributor to root yield in sweet potato. The indirect contribution of average tuber weight via number of tubers, tuber size, number of marketable tubers and number of non-marketable tubers were observed to be -0.0354, 0.0697, 0.4852 and-0.0368 respectively. Islam *et al.* (2002) reported that average tuber weight and number of tubers had positive and high direct effects on tuber weight. For this reason, these traits could be used more significantly for potato improvement.

The result of the study further revealed that total contribution of number of tubers to tuber yield was 0.4890. Hossain *et al.* (2000) reported similar result. When these were portioned into direct and indirect contribution, it was observed that -0.0753 was directly contributed through number of tubers. However, only 0.1919, 0.0384, 0.3542 and -0.0202 were contributed indirectly through average tuber weight, tuber size, number of marketable tubers and number of non-marketable tubers respectively. These findings were in accordance with the results of Galarreta *et al.* (2006).

The total contribution of tuber size to tuber yield of potato was observed to be 0.8600. Out of this, only 0.0741 was directly contributed by tuber size. Similarly, 0.3841, -0.0391, 0.4779 and-0.0331 were indirectly contributed by tuber size through average tuber weight, number of tubers, number of marketable tubers and number of non-marketable tubers respectively.

The result of the study further indicated that 0.9210 was the total contribution on number of marketable tubers to tuber yield. Out of which 0.6065 was directly contributed by number of marketable tubers. However, 0.3266, -0.0439, 0.0584 and -0.0265 were indirectly contributed by number of marketable tubers through average tuber weight, number of tubers, tuber size and number of non-marketable tubers respectively. The path coefficient analysis revealed that the direct effect on tuber yield was positive on number of marketable tubers, whereas all other characters evaluated under study exhibited direct effects (Sahu *et al.* 2017).

Table 2: Matrix of simple correlation coefficients showing association among yield related components to tuber yield of potato.

Character	TYLD/Ha	ATW_PLT	TN_PLT	TS_PLT	MTN_PLT	NMTN_PLT	TW
TYLD/Ha	1.000						
ATW_PLT	0.891**	1.000					
TN_PLT	0.489*	0.470*	1.000				
TS_PLT	0.860**	0.941**	0.519*	1.000			
MTN_PLT	0.921**	0.800**	0.584*	0.788**	1.000		
NMTN_PLT	-0.673**	-0.817**	-0.449*	-0.824**	-0.589*	1.000	
TW	1.000	0.891**	0.489*	0.860**	0.921**	-0.673**	1.000

*=Significant at $p \leq 0.05$, **= Significant at $p \leq 0.01$, TYLD/Ha=Tuber yield per hectare, ATW_PLT=Average tuber weight, TN_PLT= Number of tubers per plant, TS_PLT= Tuber size per plant, MTN_PLT=Number of marketable tubers per plant, NMTN_PLT=Number of non-marketable tubers per plant, TW=Tuber weight per hectare.

Table 3: Direct, indirect and total contribution of yield characters to tuber yield of potato.

Character	Effect through					
	Average tuber weight	Number of tubers per plant	Tuber size per plant	Number of marketable tubers per plant	Number of non-marketable tubers per plant	Total correlation
Average tuber weight	**0.4082**	-0.0354	0.0697	0.4852	-0.0368	0.8910**
Number of tubers per plant	0.1919	**-0.0753**	0.0384	0.3542	-0.0202	0.4890*
Tuber size per plant	0.3841	-0.0391	**0.0741**	0.4779	-0.0371	0.8600**
Marketable number of tubers per plant	0.3266	-0.0439	0.0584	**0.6065**	-0.0265	0.9210**
Number of non-marketable tubers per plant	-0.3335	0.0338	-0.0610	-0.3573	**0.0449**	-0.6730

Bolded= Direct contribution.

Table 4: Direct and combined contributions% of some yield characters to tuber yield of potato and their residual effect.

Character		Percent contributions
Direct contributions		
Average tuber weight	$(p_1)^2$	16.665
Number of tubers	$(p_2)^2$	0.5675
Tuber size	$(p_3)^2$	0.5485
Number of marketable tubers	$(p_4)^2$	36.7897
Number of non-marketable tubers	$(p_5)^2$	0.2023
Combined contributions		
Average tuber weight and number of tubers		-1.4453
Average tuber weight and tuber size		2.8450
Average tuber weight and number of marketable tubers		19.8084
Average tuber weight and number of non-marketable tubers		-1.5001
Number of tubers and tuber size		-0.5250
Number of tubers and number of marketable tubers		-3.6553
Number of tubers and number of non-marketable tubers		0.2768
Tuber size and number of marketable tubers		3.5938
Tuber size and number of non-marketable tubers		-0.2722
Number of marketable tubers and non-marketable tubers		-2.2288
Residual		28.3301
Total		100.0000

The total contribution of number of non-marketable tubers to tuber yield was -0.6730. Out of this 0.0449 was directly contributed by number of non-marketable tubers. Similarly, -0.0335, 0.0338, 0.0610 and -0.0 3573 were indirectly contributed by number of non-marketable tubers through average tuber weight, number of tubers, tuber size and number of marketable tubers.

Direct and combined contributions (%) of yield components to tuber yield

When the individual percentage contributions of yield components were examined, it was observed that the percentage (direct) contribution of average tuber weight was 16.6646% (Table 4). Similarly, the percentage (direct) contribution of number of tubers, tuber size, number of marketable tubers and number of non-marketable tubers to tuber yield were 0.5675%, 0.5485%, 36.7897% and 0.2023% respectively. The positive direct effect on number of tubers on tuber yield was in agreement with the findings of Alam *et al.* (1998) and Parida *et al.* (1999).

The combined contributions of average tuber weight and number of tubers was negative (-1.4453%). Similar trend was observed for the combined effects of average tuber weight and number of non-marketable tubers, number of tubers and tuber size, number of tubers and number of marketable tubers, tuber size and number of non-marketable tubers and number of marketable tubers and number of non-marketable tubers in which 1.5001%, 0.5250%, 3.6553%, 0.2722% and 2.2288% were contributed, respectively. Lavanya *et al.* (2020) reported that numbers of tubers, marketable yield, number of stems and tuber weight were the most influencing factors to improve the tuber yield. Yahaya and Ankrumah (2017) also reported that the greatest combined contributions of yield characters to grain yield in soybean were observed from number of pods per plant and number seeds per pod.

The result of the study further indicated that the combined contributions of average tuber weight and tuber size to tuber yield was 2.8450. However, 19.8084%, 0.2768% and 3.5938% were contributed by the combined effects of average tuber weight and tuber size, number of tubers and number of non-marketable tubers as well as tuber size and number of marketable tubers were contributed, respectively. Out of all these contributions, 28.3301% could not be accounted for andtherefore regarded as residual. Burhan (2007) reported that tuber yield was identified by tuber weight and average tuber weight since these characters had a positive and significant direct effect on tuber yield.

CONCLUSION

Significant and positive correlations were observed between average tuber weight, number of tubers, tuber size and number of marketable tubers to tuber yield of potato. Upon partitioning the correlation coefficients into direct, indirect and combined effects, the average tuber weight has the highest direct contribution to tuber yield. Average tuber weight and number of marketable tubers gave the highest indirect as well as combined contributions to tuber yield of potato. These traits were most influencing factors for improvement of tuber yield.

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REFERENCES

Alam, S., Narzary, B.D. and Deka, B.C. (1998). Variability, character association and path analysis in sweet potato (*Ipomoea batatas* Lam). Journal of Agricultural Science. 11: 77-81.

Atkinson, A.C. and Donev, A.N. (1989). The construction of exact D-optimum experimental designs with application to blocking response surface designs. Biometrika. 76(3): 515-526.

Burhan, A. (2007). Relationships among yield and some yield characters in potato (*Solanum tuberosum* L.). Journal of Biological Sciences. 7: 973-976.

De Galarreta, J.I.R., Ezpelata, B., Pascualena J. and Ritter, E. (2006). Combining ability and correlations for yield components in early generations of potato breeding. Journal of Plant Breeding. 125: 183-186.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research, 2nd edition. John Wiley and Sons Inc., New York.

Hossain, M.D., Rabbani M.G. and Mollah, M.L.R. (2000). Genetic variability, correlation and path analysis of yield contributing characters in sweet potato (*Ipomoea batatas* Lam.). Pakistan Journal of Science and Industrial Research. 43: 314-318.

Islam, M.J., Haque, M.Z., Majunde, U.K. and Hossain, M.F. (2002). Growth and yield potential of nine selected genotypes of sweet potato. Pakistan Journal of Biological Science. 5: 537-538.

Kareem, I.A. (2014). Inter- Relationships among the Growth and Yield Parameters of Irish Potato (*Solanum tuberosum* L.): Correlation/ regression analyses. International Journal of Advanced Research. 2(5): 27-37.

Lavanya, K.S., Srinivasa, V., Ali, S. Devaraju, Lakshmana, D. and Kadian, M.S. (2020). Correlation and path analysis for yield and yield-related traits of potato (*Solanum tuberosum* L.) in Karnataka. National Academic Science Letter. 43: 137-140.

Lemma, T., Wassu, M. and Tesfaye, A. (2020). Evaluation of potato [*Solanum tuberosum* (L.)] varieties for yield and some agronomic traits. Open Agriculture. 5(1): 63-74.

Maity, S., Chatterjee, B.N (1997). Growth attributes of potato and their inter-relationship with yield. Potato Research. 20: 337-341 https://doi.org/10.1007/BF02362245.

Majid, K.R., Shahriari, R.G., Shahzad, J. S. and Roghayyeh, Z.M. (2011). Correlation and path analysis between yield and yield components in potato (*Solanum tuberosum* L.). Middle-East Journal of Scientific Research. 7(1): 17-21.

Ndor, D.C. (2013). Survey of potato [*Solanum tuberosum* (L.)] bacterial and viral diseases in local government of plateau state Nigeria. International Journal of Emerging Knowledge. 1(4): 64-68.

Parida, A.K., Bera, M.K. and Nandi, S. (1999). Identification of parameters influencing sweet potato tuber yield under late planted rain fed condition. Journal of Environmental Ecology. 17: 971-974.

Poolman, J.M. (1959). Breeding Sugar Beets. Breeding Field Crops. Holt Rinehart and Winston Inc., New York pp. 329-352.

Sahu, G.D., Rajhansa, K.C., Purnendra, S., Eshu and Patel, K.L. (2017). Correlation and path analysis in sweet potato. Journal of Horticulture and Plant Science. 1(1): 31-34.

Sandhya, K.M., Venkataravana, P. and Pushpa, H.D. (2016). Correlation and path analysis studies in groundnut under different environment. Legume Research. 39(6): 1048-1050. DOI: 10.18805/lr.v0iOF.4484.

Supriatna, J., Nuraeni, A., Fajarfika, R. and Sahat, J.P. (2019). Correlation and path coefficient analysis of heat stress tolerance characters in potato. In Journal of Physics: Conference Series. 1402(3): 33-35.

Ugonna, C.U., Jolaoso, M.O and Onwualu, A.P. (2013). A technical appraisal of potato value chain in Nigeria. International Research Journal of Agricultural Science and Soil Science. 3(8): 291-301.

Yahaya, S.U. and Ankrumah, E. (2017). Character association and path coefficient analysis for yield components and grain yield in soybean [*Glycine max* (L.) Merill.]. Legume Research. 40(4): 630-634. DOI: 10.18805/lr.v0i0.8408.

Yahaya, S.U., Saad, A.M., Mohammed, S.G. and Afuafe, S.O. (2015). Growth and yield components of sweet potato [*Ipomoea batatas* (L.)] and their relationships with root yield. American Journal of Experimental Agriculture. 9(5): 1-7. DOI:10.9734/AJEA/2015/20078.