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Correlation study of physicochemical properties of some Sudanese onion genotypes (*Allium cepa* L.)

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Abstract
Onion is a traditional vegetable of Sudan and is by far the most popular and widely grown crop. This study was conducted to characterise the variability of selected genotypes in terms of their growth, yield and chemical characteristics. The study also examined the associations between growth, yield and chemical characteristics. Four local cultivars (Saggai, Kamleen, Baftaim and Abu Fraiwa) were used along with one introduced American cultivar (Texas Early Grano) as a check variety. The study revealed that genotypes under the study vary considerably for almost all the traits studied. Variability exists greatly for a trait such as fresh weight and pyruvic acid content recording a significantly higher standard error. The variability is also considerable for traits such as dry weight, leaf length at harvest, percentage dry weight and vitamin C. Physical parameters such as bulb polar, dry weight, leaf length, bulb diameter and percentage dry weight recorded higher heritability estimates, indicating that these characteristics can be improved by simple selection. Bulb polar, dry weight, vitamin C, protein content, leaf length at harvest and total soluble solids recorded the highest estimates for the genotypic coefficient of variability (GCV) coupled with equivalent higher values for broad sense heritability. Abu Fraiwa and Texas Early Grano showed excellent performance in almost all the characters under the study. The number of leaves and leaf length at harvest has a strong association with bulb diameter, bulb polar, fresh weight, vitamin C and pyruvic acid. Total soluble solid recorded a negative association with bulb diameter, bulb fresh weight, pyruvic acid and fiber content, suggesting that genotypes with smaller bulbs tend to have high soluble solids and a more pungent taste.

Keywords: *Allium cepa*, Sudanese onion genotypes, physical and chemical parameters

1. Introduction
Onion is a traditional vegetable of Sudan and is by far the most popular and widely grown crop from this genus in Sudan It is an important daily diet, as it is eaten raw in a salad or cooked in a wide variety of culinary dishes. Onion grows mainly in Gazira, Kassala, Northern, White Nile and the Western States. Onion may be grown three times a year, as an early winter crop from October to February, a late winter crop from January to May and an autumn crop from August to December [1]. Little is known about the variability of chemical characteristics in local Sudanese onion genotypes. The association of such characters with growth and yield parameters will enable us to establish clear visual parameters for selecting such characters. Generally, most of the studies in Sudan showed that local cultivars are reputed for their high dry matter and pungency [1, 2]. Such kinds of characters can influence other chemical characters such as TSS, carbohydrates, vitamins, ash, minerals (S, P, Mg, Mn, Ca, Cu) and oil**.** This study was conducted to characterize the variability of selected local lines in terms of their growth, yield and chemical characteristics and to study the association between them.

2. Materials and Methods
This investigation was carried out at the experimental Farm of the Faculty of Agricultural of Al Zaiem Al Azhari University in Kouko Agricultural Scheme at Khartoum North Sudan, as an early winter crop from October to February in 2018. Four local genotypes were used along with one introduced American cultivar used as a check variety. The genotypes were obtained from Plant Genetic Resources Unit, Agricultural Research Corporation (ARC), Gezira State, Sudan.

The land was prepared using a Randomized Complete Block Design (RCBD) of three replications. Each of the five plots is made in 3 m × 5 m in area. A spacing of 30 cm × 15 cm was followed and the crop was raised as per the recommended package of practices by the Agricultural Research Corporation (ARC). The observations recorded during the experiment include;

2.1 Growth and Yield Parameters
Number of leaves per plant; Leaf length at transplant (cm); Leaf length at harvest (cm); bulb diameter (cm); bulb polar length(cm); bulb fresh weight (gram) and bulb dry weigh (gram). The dry weight percentage (%) was determined as the percentage of bulb fresh weight. The bulb index was measured as the ratio of the bulb diameter and polar length. All observations were recorded as an average of 10 bulbs or plants selected at random from each plot in the three replications.

2.2 Chemical Parameters
Moisture, ash, crude protein, total soluble solids (TSS) % and ascorbic acid were determined by the recommended methods of the Association of Official Analytical Chemists [3]. The moisture content was determined by drying the samples at 105 °C to a constant weight. The ash content was dried by a laboratory furnace at 550 °C, the temperature was increased gradually and remains for 5 hours. The nitrogen content was determined using the Dumas method [4] and multiplied by a factor of 6.25 to obtain the crude protein content. Total soluble solids were recorded using a refractometer and readings were corrected to the standard temperature of 20 °C using a correction table. Ascorbic acid was determined by the indophenol method. Samples in solution were titrated with the dye until light but distinct rose-pink colour persisted for >5 s. The amount of dye used for each titration is used to calculate the ascorbic acid content in mg/100g. Pyruvic acid was measured in the reaction with 2,4dinitrophenyl hydrazine (DNPH) to form a coloured product and the result was expressed in (μmol/g) [5]. Each measurement was performed in triplicate and the results were averaged.

2.3 Statistical Analysis
A conventional RCBD analysis was used to analyze data collected on various characters to test the significance of differences among different genotypes for various characters. Variance and covariance components, phenotypic coefficient of variation (%), genotypic coefficient of variation (%), environmental coefficient of variation (%), and heritability were estimated as in [6]. The genotypic coefficient of correlation (r_g) and phenotypic coefficient of correlation (r_p) were computed described in [7] and tested for statistical significance against the correlation table values at 5 and 1% levels of significance [8].

3. Results and Discussion
Standard measures for variability were used for physical and chemical traits as per Table 1. The values recorded for minimum, maximum, mean and standard error revealed that genotypes under the study vary considerably for almost all the traits studied. Variability exists greatly for traits such as fresh weight and pyruvic acid content, recording a significantly higher standard error. The variability is also considerable for traits such as dry weight, leaf length at harvest, percentage dry weight and vitamin C. Physical parameters such as bulb polar, dry weight, leaf length, bulb diameter and percentage dry weight recorded higher heritability estimates, indicating that these characters can be improved by simple selection. This conforms with the results obtained in similar studies [9, 11] for bulb weight. This also contradicts the results obtained by McCollum [11, 12, 13] for bulb weight and diameter. The basis for variability has also been explored using the phenotypic, genotypic and environmental coefficients of variability. Bulb polar, dry weight, vitamin C, protein content, fiber content, leaf length at harvest and total soluble solids recorded the highest estimates for the genotypic coefficient of variability (GCV) coupled with equivalent higher values for heritability at broad sense. This makes these traits suitable traits for selection under field conditions as they are the least affected by the environment [14, 15, 16]. Abu ferawa and Texas Early Grano showed excellent performance in almost all the characters under the study as per Table 2 and Table 3. Abu ferawa recorded the largest number of records, with a total of eleven traits. Seven of these records are physical traits namely; leaf length at harvest (cm), the number of leaves per plant, bulb diameter (cm), bulb index, fresh weight (g), dry weight (g) and percentage of dry matter. The remaining four are chemical traits namely; vitamin (C) mg/l00g, pyruvic acid (μmol/g), ash (%) and total carbohydrate. Texas Early Grano recorded excellent performance in a total of ten traits. Seven of these records are physical traits namely; leaf length at transplant, leaf length at harvest (cm), bulb diameter (cm), bulb polar, fresh weight (g), dry weight (g) and percentage of dry matter. The remaining three are chemical traits namely; Moisture %, Pyruvic acid (μmol/g), and fiber %. Both genotypes share the highest records for traits such as leaf length at harvest (cm), bulb diameter (cm), fresh weight (g), dry weight (g), the percentage of dry weight and Pyruvic acid (μmol/g). This confirms the Texas Early Grano's long-lasting breeding value as a parent of all Sweet onions such as Granex and the Texas 1015Y. The importance of the above findings lay in presenting the breeding value of Abu ferawa as a toe-to-toe achiever with Texas Early Grano and as a possible local parent for onion breeding programmes in Sudan; considering the high estimates of heritability and genetic coefficient of variation recorded in all traits excelled by Abu ferawa. Abu ferawa can be described as a genotype of high dry weight, pungency and high vitamin C. Saggai, Baftaim, Kamlain and Abu Ferawa recorded a bulb index of 1.83, 1.77, 1.73, and 1.47 respectively. The mean separation at Table 2, classified Saggai, Baftaim, Kamlain and Abu Ferawa in one group as a flattened globe-shaped onion in contrast to Texas Early Grano, which is considered a globe shape onion. the flattened shape is an advantage for an export-based onion industry for ease of packaging. These local lines may be further used and investigated to produce more flattened onions for export. According to previous works,we concluded that Baftaim, Kamlain and Abu Ferawa can be classified as high pungency onion, recording Pyruvic acid (μmol/g) values of 33.40, 28.40, 21.70 μmol/g respectively [17].

The degree of association between the different traits has been studied as per table 4. The coefficients of correlation were further divided to elaborate on the extent of the association at the phenotypic, genotypic and environmental levels. The association between physical and chemical traits remains the core finding of this study. Such studies will pave the way for making indirect selections targeting chemical traits. The indirect selection based on correlated traits is often an effective means for saving laboratory work in developing countries where laboratory support is weak or below the standard. The positive and higher associations between bulb diameter, bulb polar and bulb index with fresh and dry weight were logical and in lieu with other reports [18, 19]. The number of leaves and leaf length at harvest has a strong association with bulb diameter, bulb polar, bulb fresh weight, vitamin C and pyruvic acid [19]. This is an expected and logical consequence of net assimilate that resulted from longer leaf length. Leaf constitute the major plant part that participates in photosynthesis and determines all growth and yield parameters in particular, [20, 21, 22]. Leaf length at harvest can be used as an indirect selection criterion for traits such as vitamin C and Pyruvic acid. Such genotypes may have strong pungency due to higher vitamin C and Pyruvic acid. Total soluble solids recorded a negative associations with bulb diameter, bulb fresh weight, pyruvic acid and fiber content, suggesting that genotypes with smaller bulbs tend to have high soluble solids and more pungent taste [12].

Table 1: Variability for physical and chemical parameters of some selected Sudanese onion genotypes

Parameters	Minimum	Maximum	Mean	PCV	GCV	ECV	Heritability Broad
Growth and yield parameters							
Leaf length at transplant (cm)	28.72	34.55	30.63	10.00	6.14	7.90	0.38
Leaf length at harvest (cm)	21.97	40.00	29.88	29.00	24.53	15.47	0.72
Number leaves per plant	6.67	8.63	7.65	13.77	9.73	9.74	0.50
Bulb diameter (cm)	5.23	8.07	6.69	24.52	20.29	13.77	0.68
Bulb polar (cm)	3.23	8.57	4.75	48.48	47.74	8.47	0.99
Bulb index	0.70	1.83	1.50	37.20	27.77	24.75	0.56
Fresh weight (g)	300.00	500.00	406.67	28.39	11.00	26.18	0.15
Dry weight (g)	90.00	200.00	158.00	36.69	36.36	4.90	0.98
Percentage dry matter (%)	27.67	40.00	34.87	15.86	12.42	9.85	0.61
Chemical parameters							
Moisture (%)	79.03	86.00	81.78	3.31	3.31	0.04	0.99
Total soluble Solids (TSS)	0.14	26.25	14.85	12.52	12.51	0.31	0.99
Vitamin (C) mg/l00 (g)	13.33	34.86	25.64	35.93	35.40	6.18	0.97
Pyruvic acid (µmol/g)	1.97	33.40	14.81	112.70	30.54	108.48	0.07
Ash (%)	4.60	5.60	5.11	9.12	7.89	4.57	0.75
Protein (%)	10.87	20.50	13.34	30.92	30.92	0.44	0.99

Table 2: Means performance for physical parameters of selected Sudanese onion genotypes

Genotype	Leaf length at transplant	Leaf length at Harvest	No. of leaves per plant	Bulb diameter (cm)	Bulb polar (cm)	Bulb Index	Fresh wt. (g)	Dry wt. (g)	% age dry matters
Saggai	29.14_{b}	22.73_{bc}	6.93_{b}	5.23	3.23	1.83	300	100	33
Kamleen	29.83_{b}	29.60_{b}	8.37_{a}	5.7	3.33	1.73	366.67	90	27.67
Baftaim	30.93_{ab}	21.97_{c}	7.67_{ab}	6.11	3.43	1.77	433.33	200	40
Abu Fraiwa	28.72_{b}	35.10_{ab}	8.63_{a}	7.7	5.2	1.47	433.33	200	37.67
Texas Early Grano	34.55_{a}	40.00_{a}	6.67_{b}	8.7	8.57	0.7	500	200	36
LSD at 5%	3.67	7.02	1.13	1.4	0. 61	0.56	161.67	11.76	5.22
LSD at 1%	5.72	10.92	1.76	2.18	0.95	0.88	251.73	18.32	8.12

Table 3: Means performance for chemical parameters of selected Sudanese onion genotypes

Genotype	Moisture %	TSS %	Ascorbic acid mg/l00g	Pyruvic acid (µmol/g)	Protein %	Ash %
Saggai	81.33	26.25	30.37	1.9 7	13.27	5.6
Kamleen	80	19.5	18.8	28.4	20.5	5
Baftaim	82.57	13.63	13.33	33.4	10.87	4.6
Abu Fraiwa	79.03	16	34.86	21.7	11.17	5.5
Texas Early Grano	86	14.1	30.86	10.87	10.9	4.87
LSD at 5%	0.06	0.07	2.41	24.4	0.09	0.36
LSD at 1%	0.09	0.11	3.75	38	0.14	0.55

Table 4: Phenotypic, genotypic and environmental coefficient of correlations

Parameter		Leaf length at harvest	No. of Leaves per plant	Bulb diameter	Bulb polar	Bulb index	Fresh weight	Dry weight	Moisture %	TSS %	ascorbic acid	Pyruvic acid	Ash %	Protein %
Leaf length at transplant	r_p	0.29	-0.42	0.34	0.61	-0.67	0.57	0.34	0.72	-0.35	0.01	-0.03	-0.46	-0.23
	r_g	0.76	-0.92	0.95	0.99	-0.98	0.98	0.55	0.97	-0.57	-0.63	-0.84	-0.79	-0.38
	r_e	-0.25	-0.03	-0.32	0.08	-0.37	0.42	0.04	-0.48	-0.16	0.37	0.14	-0.11	0.38
Leaf length at harvest	r_p		0.10	0.69	0.76	-0.60	0.34	0.37	0.27	-0.16	0.53	0.42	0.03	-0.12
	r_g		-0.09	0.95	0.95	-0.99	0.99	0.45	0.33	-0.19	0.62	0.67	-0.10	0.15
	r_e		0.41	-0.15	-0.36	0.27	-0.22	0.12	-0.14	-0.31	0.06	0.65	0.10	0.24
No. of leaves per plant	r_p			-0.10	-0.33	0.24	-0.02	0.02	-0.68	-0.18	-0.16	0.58	0.05	0.31
	r_g			-0.15	-0.49	0.61	-0.15	-0.04	-0.96	-0.25	-0.14	0.98	0.16	0.44
	r_e			-0.04	-0.07	-0.17	0.28	0.13	-0.32	-0.16	-0.48	0.35	-0.20	0.49
Bulb diameter	r_p				0.87	-0.63	0.29	0.67	0.43	-0.13	0.46	0.04	0.14	-0.47
	r_g				0.99	0.99	0.99	0.81	0.52	-0.68	0.53	0.30	0.18	-0.56
	r_e				0.65	0.20	-0.66	0.04	-0.25	-0.48	0.28	-0.05	0.05	-0.22
Bulb polar	r_p					-0.87	0.45	0.59	-0.68	-0.12	0.51	-0.03	-0.19	-0.45
	r_g					-0.97	0.99	0.59	0.69	-0.13	0.52	-0.19	-0.17	-0.46
	r_e					-0.52	-0.66	0.55	-0.45	0.56	0.38	0.12	-0.51	-0.23
Bulb index	r_p						-0.39	-0.49	-0.60	0.17	0.37	-0.10	0.28	0.33
	r_g						-0.97	-0.60	-0.81	0.22	-0.52	0.19	0.19	0.44
	r_e						0.13	-0.50	0.02	-0.01	0.03	-0.07	0.46	0.17
Fresh weight	r_p							0.95	0.37	-0.34	-0.10	-0.04	-0.32	-0.33
	r_g							0.96	0.95	-0.83	0.17	0.97	-0.95	-0.86
	re							-0.18	0.28	0.62	-0.46	-0.18	0.08	0.29
Dry weight	r_p								0.39	-0.14	0.13	-0.10	-0.38	0.82
	r_g								0.39	-0.15	0.13	-0.28	-0.31	-0.82
	r_e								-0,09	-0.07	0.13	0.50	-0.98	-0.16
Moisture % age	r_p									-0.26	-0.03	-0.32	-0.50	-0.42
	r_g									-0.27	-0.03	-0.96	-0.58	-0.38
	r_e									-0.44	-0.58	-0.44	0.11	-0.39
TSS % age	r_p										0.68	-026	0.99	-0.36
	r_g										0.69	-0.97	0.90	-0.36
	r_e										0.41	-0.35	0.20	-0.30
ascorbic acid	r_p											-0.07	0.47	-0.34
	r_g											-0.46	0.80	-0.35
	r_e											-0.32	-0.08	0.15
Pyruvic acid	r_p												-0.25	0.37
	r_g												0.07	0.98
	r_e												-0.55	0.49
Ash	r_p													0.02
	r_g													0.03
	r_e													0.09

4. Conclusion

Abu ferawa is an excellent candidate for any future breeding programs and need more investigation to measure its relative breeding merit in terms of its specific crossing value represented in GCA and SCA respectively along with compatible genotypes. Abu ferawa can be used in evolving genotypes of high dry weight, pungency and high vitamin C content. Leaf length at harvest is a good trait to select for high vitamin C and pyruvic acid. Saggai, Baftaim, Kamlain and Abu Ferawa can be used as possible parents to produce a flattened globe-shaped onion for export.

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