HERITABILITY AND CORRELATION STUDIES IN NIGERIAN LOCAL WHITE ONION *Allium cepa* L.

BY

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DATE: 14th JULY,1983

DECLARATION

I hereby declare that this thesis has been composed by myself and that it is a record of my own research work. It has not been accepted in any previous application for a higher degree. All quotations are distinguished by quotation marks and the sources of information are specifically acknowledged by means of references.

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INTRODUCTION

Onion (*Allium cepa* L.) is the most common among all the bulbous vegetable crops classified in the genus Allium within the family liliaceae. In Nigeria there are several local cultivars of Onion with distinct characteristics, such as colour, shape, and pungency. Onion production in Nigeria is located mainly within the northern states, especially in the areas between latitudes 10° and 13°N. The commercial production of the crop is mainly during the dry season, because of disease problems associated with the wet season. Thus onion production in Nigeria is mainly carried out in the local Fadama areas because these are the areas with irrigation water. Quite recently however, the Federal Government has increased the amount of irrigatable lands through construction of many dam projects. Hence onion production has extended beyond the fadama areas.

The traditional methods employed in onion production by the local farmers are usually responsible for their low productivity. The average low yield of approximately 5 tons per acre is because of very low plant densities, poor seed germination, and lack of appropriate fertilizer application.

Most research observations conducted have shown that the red or brown skinned onions are prefered by Nigerian

Consummers, because they have been found to store better than the yellow or white ones (Green 1973). It has also been shown that the red skinned onion is more resistant to storage pathogens because of the antibiotics associated with the red pigments, and also because of their high soluble solids contents. The local white cultivar that is not liked by consummers are mostly used for medicinal purposes by the indigins. The reason for this is still not known. However, the white local onion is only distinct from the other Nigerian onions in terms of its colour which is thought to be due to reccessive gene effect on colour (personal communication with Van Amstel, Onion breeder Horticultural Section, I.A.R.).

This study was conducted primarily to study the genetic variances and correlations among traits in our local white onion cultivars. Secondly, to study, the heritable variations within these traits in order to ascertain whether breeding for these traits should be undertaken.

LITERATURE REVIEW

A. Dry Matter Content

The dry matter content of onion varieties especially those to be used in industrial processing for dehydration is of great importance to breeders. The development of desirable lines involves selection of individual bulbs containing known amounts of dry matter. This type of selection presents some problems because onions for breeding are first grown from seeds in the first year to produce bulbs which are then examined for the desirable characters. The selected bulbs are planted out the following year for seed production. In determining the dry matter content of individual bulbs, one must remove a portion of the bulb for analysis, that is a sample representative of all the tissues is taken and this is usually done by cutting parellel to the axis of the bulb. Bulbs that are sampled this way are difficult to store for latter planting due to spoilage caused by organisms which enter through the wounds caused by sampling. Since the sampling is done on large population of bulbs, such losses are serious.

To avoid spoilage, other methods of sampling have been tried. The outer-most two fleshy scales of the bulb may be removed with very slight injuries, and the juice from the pieces are squeezed out and a drop is

place on a refractometer which gives the percentage sugar content in the bulb. The analysed bulb can then be stored for a long period without spoilage.

Biryukov (1939) used this method and showed that the refractive index or percentage sugar content is positively related to dry matter content. From his calculations he found a correlation of r = 0.96 for dry weights (oven dry) and refractometer readings. Mann and Hoyle (1945), McCollum (1966), and Harris and Vilece (1970), used this method and obtained similar results.

Foskett and Peterson (1950) showed that varieties or hybrids of onion having high percentage of dry matter are less likely to sprout during storage, than those with low dry matter. In their study Mann and Hoyle (1945) found that the percentage of dry matter in South White Globe increased from outer to inner scales of the entire bulb. This means that sample taken from smaller portion rather than the entire bulb used as sample could give rise to misleading statistics. It was also shown by Kehr and Tims (1951) and Zeller (1939) that percentage of soluble solutes in creole onions and the concentration of sugars in an unspecified cultivar increased from outside to inside and from top to bottom of the onion bulb.

B. Bulb Firmness

Onion harvested in commercial quantities are stored in bulk to a height of 2.5 - 4 meters. Using the existing varieties, stacking to approximately 3 meters is satisfactory in the temperate areas, but higher stacking sometimes results in crushing or detormation of bulbs at the base.

However, now varieties with increased resistance to detormation would permit stacking to greater height, and hence lead to increased storage effeciency. Thus many onion breeders include bulb hardness (firmness) as a quality characteristics in their programmes.

Measurement of the bulb firmness have been made by Magruder and Knight (1933) and Ang et al (1959) using the LEE Frame Shear press and expressed the bulb firmness as an F/D ratio where F is the force applied in Kilograms and D the distance of compression in centimeters. However Fennell (1977) on the other hand used a small compression tester called the durometer, originally used for testing fruit firmness in cherries (Unrath et al (1969) and tuber firmness in potatoes (Ross and Poter (1976). He also compared the durometer for testing hardness in onion bulbs with a tensile testing machine. Results from the two tests were closely correlated and significant varietal differences were detected in bulb hardness by both machines. The durometer was of particular value because of its simpli-

city and non destructive nature of the test procedure. Niewhof et al (1973) used different methods for measuring onion bulb firmness. Such methods include, Hand or thumb pressure, tenderometer, durometer and penetrometer, and found no strong correlations between the results of these different methods of measurements.

C. Bulb Weight

Mann and Hoyle (1945) in their examination of four varieties of onions, noted that those with low mean dry matter had relatively larger bulbs, especially are Italian Red and California Early Red, while varieties with high dry matter had smaller bulbs, like South Port White Globe and Australian Brown.

From the experiment Niewhof (1973) carried out in cooperation with the dutch onion Federation from 1965 - 1968 using mainly the strains of Rejnsburg and Noth Holland Straw Yellow, it was evident that the most productive strains had the lowest dry matter content. With an increase in dry matter content of 1 per cent the productivity decreased by 10 per cent. Also Niewhof (1973) cited an example, that the dry matter content of Wolska strain is 1 to 2 per cent higher than that of most Rijnsburg strains, but the productivity is 10 to 20 per cent lower. McCollum (1968) observed that there are

tendencies for a negative genetic correlation - between dry matter content and bulb weight. He suggested that when selecting for a higher dry matter content, attention should also be paid to the effect of this on yield. On the other hand, Fennell (1977) using open pollinated and hybrid varieties found no correlation between bulb size and firmness.

D. Vegetative Characters

Several methods for estimating the area of leaves have been developed and described. The equation, leaf area = Leaf Width (w) x Leaf Length (L) x a factor (F), has been used successfully with a number of species. McKee (1963) used this method in corn (Zea may L.) Ashley *et al* (1963) used it in cotton and Stickler *et al* (1961) used it in sorghum. The factor (F) is usually determined by tracing the outlines of sampled detached leaves on a graph paper, or on a paper and the area is subsequently determined with a planimeter. The width and length of the detached leaves are also measured. These measurements are then used to determine the factor (F) in the following equation $\frac{\text{Leaf area}}{L \times W}$. Hoffman (1971) in his own different approach, found a logarithmic relationship between leaf length and leaf area for hybrid Granex onion.

On leaf length and yield of onion, Howthorn (1946)

and Delis et al (1967) in their works found a positive correlation between the two traits. Dowker et al (1976) also reported a positive correlation between leaf length and yield in onion. These workers however showed lower correlations between plant yield and leaf characters such as width of longest leaf, leaf number, and neck diameter as compared to the correlations of + 0.82 between leaf length and yield which they obtained. This is the reason therefore why leaf length has been choosen as the best available measurement of plant size.

E. Heritability of Onion traits

Heritability of onion traits have been investigated by several workers in different onion cultivars, and variable levels of heritability have been reported.

McCollum (1968) estimated heritability in Yellow Sweet Spanish onion, and found the values for bulb weight and diameter were mostly very low 0-11 per cent and 0-23 per cent respectively, while the values for bulb length and shape index were 25 - 76 per cent and 34 - 68 per cent respectively. Nakamura (1958) estimated heritability in three successive years 1956, 1967, and 1958 for bulb weight and obtained heritability estimates of 10, 0, 0 per cent respectively. Warid (1959) working on green house onions estimated heritability of soluble

solids to range from 71 - 73 per cent. Similarly McCollum (1968) in another work with open pollinated White Sweet Spanish cultivar obtained heritability of 90 per cent for soluble solids (dry matter content).

Because of this high heritability exhibited by soluble solids both Warid (1952) and Owens (1951) concluded from their genetic studies that selection would be effective to change solids content of onions.

MATERIALS AND METHOD

Plant Material

Local white bulbs used in this experiment were collected from markets and villages in and around Zaria township. These bulbs were planted and seeds raised from them were grown to produce bulbs in 1979/80 dry season. The harvested bulbs were stored from April to September 1980 during which sprouted and rotten bulbs were frequently removed forthnightly.

In September 1980, 460 numbered bulbs were analysed for bulb firmness by the use of durometer as was described by Fennell (1977). The analysis for soluble solids was measured by hand refractometer as outlined by Mann and Hoyle (1945). Finally bulb weight was dertermined by weighing the bulbs on a scale.

From the 460 bulbs, 100 bulbs were selected at random. The mean values for bulb firmness, Soluble solids, and bulb weight for the 100 randomly selected bulbs were 71.79 per cent 8.69 per cent and 99.12 grams respectively as shown in table 1.

Experimental Proceduce

To understand clearly the following methodology, one must understand that the onion plant is a biannual crop. In the first year bulbs are planted usually during

the beginning of the dry season (October). After six months (March) onion seeds are harvested. These harvested seeds when sown and transplanted on to the field in the next dry season, onion bulbs will be produced again, thus completing the circle.

In October 1980 therefore, the 100 bulbs were planted in an isolated field free from other sources of pollen, for the production of maternal half-sib family seeds. During the growth period, all agronomic performances were carried out, such as fertilizer application, weeding and diseases and pests control, according to stipulated recommendations. No experimental design was used as it was purely a seed multiplication plot.

Open pollination occured, thus each plant was equally likely to act as pollen parent to each of the families. (Variations in plant vigor and bloom date probably prevented complete randomness of the matting).

It is also possible for self pollination to have occured which by the estimation procedures used would bias the heritability estimates upward. However, onion is a species which is naturally cross-pollinated by insects and selfing, unless enforced by isolation from other pollen sources, is not expected to be of any consequence.

In April 1981 seeds from each mother bulb were harvested separately, thus constituting a series of

maternal half-sib family seeds. Environmental hazards such as diseases, and inadequate water supply affected survivability of some family lines, and hence only 30 maternal half-sib family seeds were obtained.

In May 1981 the seeds from each half-sib family was sown and transplanted in early July. The experiment failed because of onion twister disease which is very common during the wet season.

The experiment was replanted in October 1981 and transplanted after six weeks on a bed 4 meters long by 2 meters wide, with a spacing of 15 cm between rows and 20 cm within row. Thus about eight rows were obtained per plot. A randomised complete block design with two replications was used due to limitation of seeds, and fertilizer (Superphosphate) was applied before transplanting and top dressed after six weeks of planting with calcium ammonium nitrate fertilizer. Weeding and pest control was done as recommended by Institute for Agricultural Research Zaria.

At about two weeks to harvest 15 plants on each plot were chosen at random in the two center rows, and the following measurements made on the vegetative characters:- Number of leaves, length of longest leaf, width of longest leaf, leaf area of longest leaf. About 2 weeks after harvest these other measurements were made on the harvested bulbs, viz Soluble solids, bulb firmness and bulb weight.

Number of leaves: The number of leaves for each of the 15 plants sampled was recorded. The total number was

divided by 15 to give the mean number of leaves per plant.

Length of longest leaf: Measurement was made from the base to apex of the longest leaf on each plant sampled. The measurement was in centimeter.

Width of Longest Leaf: This measurement was also made on the width of longest leaf by flattening the leaf and measurement was taken at the widest portion in centimeters, using a meter rule.

Leaf Area: This was determined by the use of the formular (L x W) x a factor (F). The factor was obtained from samples of leaves taken prior to the actual measurement. These sampled leaves were detached from the main plants at their bases, and their length, width, and leaf areas were determined by tracing the leaves outlines on a centimeter graph paper. The factor (F) was then calculated by the formular $\frac{\text{estimated leaf area}}{(L \times B)}$.

Soluble solids: The outer three fleshy scales of the onion bulbs were removed out on three places round the middle of the bulb, using a borer. The pieces were removed and placed on a crusher, which squeezed out the juice. A drop of the juice was placed on the hand refractometer which recorded the amount of sucrose sugar in percentage.

Bulb Firmness: A durometer, model O-2 manufactured by the Shore Instrument Manufacturing Company Inc. Jamaica, New York, U.S.A. was used. This instrument measured the bulb firmness in percentage.

Bulb Weight: Individual bulbs were weighes on a mettler P1210 Scale. The readings were recorded in grams.

Statistical Analysis

Analysis of variance was performed for all the traits from the experiment. The analysis for each trait was computed on plot means.

The form of the analysis of variance with the expected mean squares which were used for the estimation of genetic parameters is shown in table 2. The components of variance were estimated from the expected mean square for the analysis of half-sib families as in table 3.

Table 4 shows the analysis of variance and covariance of a pair of characters (x and y) with the expected mean cross-products. The analysis of covariance for a pair of all the traits is obtained by the combination of the analysis of variation for both traits in the pair.

The genotypic and phenotypic correlations were estimated for pairs of all traits measured. Calculations on genotypic correlation coefficients were made from the component of variance. In this procedure the analysis of variance and covariation (table 4) were used to obtain genotypic components of variance and covariation according to the formular used by Mode and Robinson (1959).

$$\sigma_{Gx} = \frac{\sigma^2_{G\ x\ Gy}}{\sqrt{\sigma^2_{Gx} \cdot \sigma^2_{Gy}}}$$

Where σ^2_{GXGY} is the genotypic covariance of traits X and Y

σ^2_{GX} is the genotypic variance of trait X

σ^2_{GY} is the genotypic variance of trait Y

σ^2_{gxy} is the genotypic correlation coefficients of the two traits X and Y

The phenotypic correlation were computed using formular

$$rph = \frac{M_3 \quad M_3^1}{\sqrt{M_3 \cdot M_3^1}}$$

Where M_3 is the entry mean square for trait X

M_3^1 is the entry mean square for trait Y

and $M_3\ M_3^1$ is the entry mean product for the two traits X and Y.

The error correlation was also computed for each pair of all traits measured using the error mean square. This is a measure of the effects of replications on the traits in each pair. The formular used was :- $rexy = \frac{M_5 \quad M_5^1}{\sqrt{M_5 \times M_5^1}}$

Where rexy is the error correlation coefficient for trait x and y.

M_5 is the error mean square for trait X

M_5^1 is the error mean square for trait Y

and $M_5\ M_5^1$ is the error mean cross-product for traits X and Y.

Two estimates of heritability defined in the narrow sense as a ratio of additive genetic variance to total phenotypic variance i.e. $h^2 = \frac{VA}{Vp}$ were used.

The first estimate required the standard regression coefficient of half-sib family means on mother bulb values (regression of offspring on one parent). The formula used was:- $\frac{(X - \bar{X})\ (Y - \bar{Y})}{\Sigma (x - \bar{X})^2}$

With a standard error S.E. = $\sqrt{\frac{S_{Y \cdot X}}{\Sigma X^2}}$

Where X is the parent trait

Y is the offspring trait

Thus $b_{op} = \frac{Cov \cdot op}{Vp}$

Where Vp = maternal parent variance

V_A = additive genetic variance

Cov OP = $\frac{1}{2}$ VA

$\therefore b_{op} = \frac{\frac{1}{2} VA}{Vp}$

and VA = $2(b_{op} \cdot Vp)$

$\therefore h^2 = \frac{VA}{V_B + V_R + V_W}$

Where V_B = Between half-sib families

V_R = Reps / families

V_W = Within families

The second estimate required the variance component obtained in the analysis of half-sib families (table 2). The formular used is $t_{Hs} = \frac{\frac{1}{2} VA}{Vp} = \frac{\sigma^2_B}{\sigma^2_T}$ with standard error S.E. $\frac{\sigma^2}{\sqrt{n}}$

$$t = \frac{V_B}{V_B + V_V + V_W} = t = \frac{\frac{1}{2} VA}{V_B + V_R + V_W}$$

$$\tfrac{1}{2} VA = t (V_A + V_R + V_W)$$

$$V_A = 4t (V_B + V_R + V_W)$$

$$\text{i.e. } h^2 = 4t\, V_B + V_R + V_W \,/\, V_B + V_R + V_W$$

$$h^2 = \frac{4 V_B}{V_B + V_R + V_W} = \frac{4 V_B}{1.0 (V_B + V_R + V_W)}$$

As modified by Bohren et al (1965) when only one parent is identified.

RESULTS

Table 1, gives the mean values, standard errors, range and coefficient of variability for the three bulb traits; bulb weight, bulb firmness, and soluble solids for the 100 randomly selected bulbs and the 30 bulbs that survived enough to generate the half-sib families. The mean values for bulb weight, bulb firmness and soluble solids are 99.12 grams 71.79 per cent and 8.69 per cent respectively.

The values for the 30 bulbs that generated the 30 half-sib families for the three mentioned traits, namely bulb weight, bulb firmness and soluble solids are 103.30 grams, 71.28 per cent and 8.66 per cent respectively. From these data, there are no significant differences in the mean values for the traits observed in the 100 randomly selected bulbs and the 30 bulbs that survived enough to generate the half-sib families.

The standard errors for the mean values for bulb weight, bulb firmness and soluble solids range from 0.15 to 3.73 for the randomly selected bulbs, while the range for the 30 bulbs that survived was 0.24 to 6.49.

The coefficient of variability was high in both the randomly selected bulbs and the 30 bulbs that survived compared to the other traits as shown by their values (37.66, 34.47) for bulb weight (7.04, 8.08) for bulb firmness and (16.63, 15.24) for soluble solids.

Table 1. Mean, Standard Error (S.E.), Range and Coefficient of Variability (%) for Bulb weight, Bulb firmness and Soluble Solids in Local white onion.

Traits	Mean(g)	Standard Error	Range	Coefficient & Variability (%)
Bulb Weight	99.12 ±	3.73	44.0-249.08	37.66
	(103.30 ±	6.49)	(54.0-186.28)	(34.47)
Bulb firmness	71.79 ±	0.51	56.0-82.0	7.04
	(71.28 ±	1.05)	(59.2-80.5)	(8.08)
Soluble Solids	8.69 ±	0.15	5.7-12.9	16.63
	(8.66 ±	0.24)	(6.2-12.9)	(15.24)

Upper row for each trait refers to 100 randomly selected bulbs and lower row in bracket to the 30 mother bulbs that generated the half-sib families.

The estimates of variance components and their method of determination are given in the analysis of variance and the expectation of mean squares in table 2. The importance of components as sources of variation is indicated by their relative magnitute. The between half-sib families and reps in families variations were highly significant at (1 per cent level of probability) for bulb weight, bulb firmness and soluble solids, number of leaves per plant, length of longest leaf, width of longest leaf and leaf area of longest leaf as shown in table 3.

The components of variance for bulb weight and leaf area of longest leaf were high σ^2_B = 82.5 and - 149.3, while their error are σ^2_w = 1311.3 and 1160.0 respectively. Bulb firmness and length of longest leaf were moderately high with σ^2_B = 2.131 and -2.199, while their σ^2_w = 24.390 and 27.450 respectively. The lower components of variance were obtained in soluble solids 0.6055, number of leaves per plant 0.1664 and width of longest leaf 0.0087 and their respective error variance σ^2_w = 2.352, 2.261 and 0.484 respectively.

Heritability Estimates

The variation in heritability estimates using intra-class correlation showed low estimate of 0.058 for width of longest leaf and intermediate estimates of 0.20 for bulb weight, 0.25 for number of leaves per plant, -0.27

Table 2. Form of ANOVA of Half-Sib families

Sources of Variance	Degrees of Freedom	M.S	Expected mean squares
Between half-sib families	b-1	M_3	$\sigma^2_W + K\sigma^2_R + K\sigma^2_B$
Reps in families	b(r-1)	M_2	$\sigma^2_W + K\sigma^2_R$
Within reps in families	(N-br)	M_1	σ^2_W

Where b = 30

r = 2

N = 600

K = 10

b = number of families

r = the number of replications

N = the total number of individuals sampled

K = the number of samples taken (Snedecor, 1956 Section 10.17).

M_1 = Mean squares of within reps in families

M_2 = Mean square of reps in families

M_3 = Mean square of between half-sib families

B = Expected mean square for between half-sib families

W = Expected mean square value for within reps in families

R = Expected mean square value for reps in families.

Table 3. Mean squares and Components of Variance in the analysis of half-sib families

Sources of Variation	Degrees of Freedom	Bulb Weight	Bulb firmness	Soluble Solids	No. of leaves per plant	Length of longest leaf	Width of longest leav	Leaf area of longest leaf
Between half-sib families	29	4814**	46.80**	12.440**	5.259**	72.55**	1.6672**	2452**
Reps in families	30	3989**	25.49**	6.385**	4.259**	94.54**	1.5802**	3945**
Within reps in families	540	1311	24.39	2.352	2.267	27.54	0.4836	1160
			COMPONENTS OF VARIANCE					
σ^2_S		82.5	2.131	0.6055	0.1664	-2.199	0.0087	-149.3
σ^2_R		267.8	0.110	0.4033	0.1992	6.700	0.1097	278.5
σ^2_W		1311.3	24.390	2.3520	2.2670	27.540	0.4836	1160.0
σ^2_T		1661.6	26.631	3.3610	2.6330	32.044	0.6020	1289.2

** Significant at both 1% and 5% Levels.

Table 4. Form of ANOVA, Covariance and E(M.S) Products for pairs of Characters X and Y

Sources	Degrees of Freedom	Mean Squares	Traits	Mean Product	Expected mean squares mean product
Between		X	Y	XY	
half-sib families		M_3	M_3^1	$M_3M_3^1$	$\sigma^2_{XY} + \sigma^2_{GRXGRY} + \sigma^2_{GXGY}$
Reps in families		M_4	M_4^1	$M_4M_4^1$	$\sigma^2_{XY} + \sigma^2_{GRXGRY}$
Within Reps in families		M_5	M_5^1	$M_5M_5^1$	σ^2_{XY}

Where σ^2_{GXGY} is genotypic covariance of trait X and Y

σ^2_{GX} is genotypic variance of trait X

σ^2_{GY} is genotypic variance of trait Y

Table 5. Heritability of traits estimated from intra-class Correlation with Standard errors.

Traits	Heritability from Intra-class Correlation
Bulb Weight	0.1986 ± 2.87
Bulb firmness	0.3200 ± 0.46
Soluble Solids	0.7206 ± 0.25
No. of leaves per plant	0.2530 ± 0.13
Length of longest leaf	-0.2740 ± 0.47
Width of leaf	0.0578 ± 0.03
Leaf area of longest leaf	-0.4630 ± 3.87

for length of longest leaf. Moderately high values were obtained for bulb firmness 0.32 and leaf area of longest leaf -0.46. The only high value was obtained in the soluble solids 0.72.

Using the parent offspring - regression estimates for calculation of heritability on only three traits the values were moderately high for bulb weight and bulb firmness 0.386 and 0.333 respectively. The high value of 0.576 was obtained in the soluble solids.

Correlation Coefficients

Correlation Coefficient were computed from the combined analysis of variance and covariance (Table 4) All possible phenotypic, additive genetic and error correlations were computed for all the seven characters within the half-sib families under study.

Table 7 shows the phenotypic correlation coefficients (r_{ph}) among characters for the half-sib families. A negative significant phenotypic correlation (P=0.05) exists between bulb firmness and bulb weight. However bulb firmness had positive non significant correlations with soluble solid 0.0079, and number of leaves per plant 0.0579. While it has a negative non significant correlations with length of longest leaf -0.0618, width of longest leaf -0.0163 and leaf area of longest leaf -0.0265.

Table 6. Heritability of Bulb traits estimated from half-sib offspring on parent regression with standard errors

Traits	Heritability from offspring parent regression
Bulb Weight	0.368 ± 2.830
Bulb firmness	0.333 ± 0.279
Soluble Solids	0.576 ± 0.148

Table 7. Phenotypic Correlation Coefficients (r_{ph}) among Seven Characters for the 30 half-sib families

Traits	Bulb firmness	Soluble Solids	Bulb weight	No.of leaves per plant	Length of Longest leaf	Width of Longest leaf	Leaf Area of longest leaf
Bulb firmness		0.0079	-0.0845*	0.0579	-0.0618	-0.0163	-0.0265
Soluble solids			-0.2631**	0.0152	-0.0813*	0.0547	-0.0662
Bulb weight				-0.0380	-0.0488	0.0454	-0.0020
No. of leaves per plant					0.0192	0.0650	0.0483
Length of Longest leaf						0.4203**	0.7002**
Width of Longest leaf							0.8212**
Leaf Area of Longest leaf							

** Significant at 1% and 5% level of probability

* Significant at only 5% level of probability

Soluble solids showed a negative highly significant correlation with bulb weight -0.263, but only a negative significant correlation with length of longest leaf -0.0813. With number of leaves per plant, width of longest leaf, it had a positive but non significant correlations (0.0152 and 0.0547) respectively. Bulb weight and Number of leaves per plant had non significant correlations with all the remaining traits. However, bulb weight had a negative non significant correlations with number of leaves per plant -0.0380, length of longest leaf -0.0488, and leaf area of longest leaf 0.0020, but a positive one with width of longest leaf 0.0454. The association between number of leaves per plant were all positive and non significantly correlated with all the other traits.

Length of longest leaf displayed a positive and highly significant correlations with width of longest leaf 0.4203 and leaf area of longest leaf 0.7002. While width of longest leaf also had a highly significant positive correlation with leaf area of longest leaf 0.8212

Table 8 shows the additive genetic correlation coefficients (r_A) among all the seven traits under study. Generally most of the correlation values are positive and statistically highly significant. Bulb firmness for instance showed a highly significant correlations with soluble solids 0.495, number of leaves per plant 0.346, length of longest leaf 0.830, width of longest leaf 0.188 and leaf area of longest

Table 8. Additive genetic Correlation Coefficients (r_A) among Seven Characters for the 30 half-sib families

Traits	Bulb firmness	Soluble Solids	Bulb Weight	No.of Leaves per plant	Length of Longest Leaf	Width of Longest Leaf	Leaf Area of Longest Leaf
Bulb firmness		0.495**	0.095*	0.346**	0.830**	0.188**	0.137**
Soluble Solids			0.044	0.321**	0.390**	0.382**	0.068
Bulb Weight				0.035	0.120**	0.018	0.704**
No.of leaves per plant					0.286**	0.531**	0.049
Length of Longest leaf						0.156**	0.101*
Width of Longest leaf							0.011
Leaf area of Longest leaf							

** Significant at 1% and 5% levels of probability

* Significant at 5% level of probability

leaf 0.137, but with bulb weight it only had a significant correlation (P= 0.05) of 0.095.

Soluble solids showed a highly significant correlation with number of leaves per plant 0.321, length of longest leaf 0.390, and width of longest leaf 0.382, but a non significant correlation with bulb weight and leaf area of longest leaf 0.044 and 0.068 respectively. Similarly bulb weight had a high significant correlation with length of longest leaf and leaf area of longest leaf 0.120, and 0.704 respectively. Number of leaves per plant had a highly significant correlation with length of longest leaf 0.286, width of longest leaf 0.531, but a non significant correlation with leaf area of longest leaf 0.049. Length of longest leaf also exhibited a highly significant correlation with width of longest leaf 0.156, and only a significant association with leaf area of longest leaf. Width of longest leaf and leaf area of longest leaf however had no significant correlation between them 0.011. Table 9. shows error correlation coefficient (r_e), and all the values are positive, and mostly highly significant. Bulb firmness had highly significant correlations with all the other six traits, namely soluble solids 0.311, bulb weight 0.136, number of leaves per plant 0.305, length of longest leaf 0.931, width of longest leaf 0.141 and leaf area of longest leaf 0.145. Soluble solids on the other hand had a highly significant correlation with length of longest leaf, and width of longest

Table 9. Error Correlation Coefficients (r_e) amomg Seven Characters for the 30 half-sib families

Traits	Bulb firmness	Soluble Solids	Bulb Weight	No. of Leaves per plant	Length of Longest Leaf	Width of Longest leaf	Leaf Area of Longest Leaf
Bulb firmness		0.311**	0.136**	0.305**	0.931**	0.141**	0.145**
Soluble Solids			0.041	0.020	0.292**	0.453**	0.045
Bulb Weight				0.042	0.145**	0.019	0.942**
No.of Leaves per plant				0.287**	0.459**	0.042	
Length of Longest leaf					0.112**	0.008	
Width of Longest leaf						0.007	
Leaf area of Longest leaf							

** Significant at 1% and 5% level of probability

* Significant at 5% level of probability.

leaf (re = 0.292 and 0.453) respectively, but showed a non significant correlation with bulb weight 0.041, number of leaves per plant 0.020, and leaf area of longest leaf 0.045. Similarly bulb weight had a highly significant correlation with length of longest leaf 0.145 and leaf area of longest leaf 0.942, but a non significant correlation with number of leaves per plant 0.042 and width of longest leaf 0.019.

Number of longest leaf displayed a highly significant correlation with length of longest leaf 0.287 and width of longest leaf 0.459, but non significant correlation with leaf area of longest leaf. Length of longest leaf also showed a highly significant correlation with width of longest leaf 0.112. Leaf area of longest leaf had no significant correlation with length of longest leaf, and width of longest leaf 0.008 and 0.007 respectively.

DISCUSSIONS

Except for the bulb weight where the range of the mean value was from 44.0 - 249.08 the other values for the remaining traits had a more closer range. This effect resulted in the high coefficient of variability for both the 100 randomly selected bulbs and the 30 bulbs that generated the half-sib families 37.66 and 34.47 respectively. The other traits, bulb firmness and soluble solids where the range for the mean value is closer, the coefficient of variability is 7.04 and 16.63 respectively for the 100 randomly selected bulbs and 8.08 and 15.24 for the 30 bulbs that generated the half-sib families respectively.

Table 1 also showed that the high bulb weights of 99.12 grams for the randomly selected bulbs had corresponding low soluble solids for the same bulbs, do not necessarily contain high dry matter.

In comparison the 30 bulbs that generated the half-sib families and the 100 randomly selected bulbs were very similar in values as shown in Table 1.

The method of estimation of variance component is whown in Table 2. All the estimates were positive except for length of longest leaf, and leaf area of longest leaf. The estimates of variance components as shown in Table 2, were of high magnitude especially for bulb weight and leaf area

of longest leaf and this could have created biased estimates in the values of some traits. The estimate of the components of variance could however be biased if variation in plant vigor and bloom date prevented complete randomness. And also if self-pollination had occured (McCollum 1968). However, onion is a species naturally cross-pollinated by insects, and selfing unless enforced by isolation from other pollen sources is not expected to be significant. In the absence of experimental evidence to the contrary, according to McCollum (1968) the frequency of progeny produced by selfing within a population supplied with adequate pollinating insects is not expected to exceed that which would occur from random mating.

Heritability

Both estimates of heritability in Tables 5 and 6 were made on the assumption of negligible epistatic interaction, because espistasis would bias them upward. Also the estimates could be biased by the selection of parents, since only bulbs that did not rot or sprout prematurely in storage were chosen. According to McCollum (1968) it is generally accepted that dry matter is in some way related to storability. For instance, Foskett (1949), found that in a group of several different cultivars and hybrids, that there was a inverse relationship between refractive index of expressed juice and the amount of sprouting in storage.

Early Yellow Grobe (9.9 per cent) and Texas Grano 5.5 per cent, range 4.3 to 8 per cent) postulated commulative gene action of a relatively small number. Owen (1951) and Warid (1952) concluded from their genetic studies that selection would be effective to change soluble solids contents of onions.

The lower heritability estimates obtained by offspring-parent regression method in Soluble Solids, and higher in bulb weight as compared to the intra-class correlation is not unexpected. In earlier studies Robinson et al (1949) and Frey and Hamer (1955) showed that parent offspring regression method of estimating heritability gave lower heritability values than the variance component method. More recent studies by Foster et al (1967) has confirmed these obser-vations, and could be biased upward due to inter-generation regression as already mentioned above.

Where the standard error of heritability exceeds the actual value, no great reliability is expected to be placed on the estimates.

Correlation Coefficients

Generally most of the phenotypic correlations Table 7 are small and mostly non-significant, except in the correlation between bulb weight and Soluble Solids which showed a significant negative correlation. This shows that for an increase in dry matter content there is a decrease in bulb weight. Similar observations have been made by Mann and Hoyle

(1945), McCollum (1968), and Niewhof (1973).

The low negative phenotypic correlation values for bulb weight and Soluble Solids would suggest that very little can be gained by trying to adjust for bulb weight in Soluble Solids selection programme.

The significant phenotypic association between leaf area and length of longest leaf and width of longest leaf also shows how positively dependent each of these traits is on the other.

Most of the additive genetic correlations (r_A) were positive and statistically significant (P = 0.05 and 0.01). Although most of the values were small, it may be assumed that genetic factors are responsible for the associations of the paired characters. Similar genotypic correlation values observed here have been reported by Owens (1951) Mann and Hoyle (1945), and McCollum (1968).

The high genetic correlation between bulb weight and leaf area of longest leaf (r_A) = 0.704) compared with environmental error (r_e = 0.942) means that the environment seems to influence bulb weight and leaf area of longest leaf which are traits with low heritability (0 to 0.19 and 0 to -0.46) respectively.

SUMMARY

Heritability of bulb weight, bulb firmness, soluble solids, number of leaves per plant, length of longest leaf, width of longest leaf and leaf area of longest leaf of onion cultivar local white were estimated in two ways (1) By calculating regression of half-sib offspring on female parent (1st three traits only) and (2) By calculating half-sib family intra-class correlations.

The heritability estimates for soluble solids was high (72%), bulb weight, bulb firmness, number of leaves per plant, length of longest leaf, width of longest leaf (20%, 32%, 25%, 27%, and 6%) respectively were low. Leaf area of longest leaf was intermediate (46%). From the data the phenotypic additive genetic and error correlations between traits were calculated. Among the statistical result observed were the high positive genetic correlations and high error correlation between bulb firmness and length of longest leaf, (0.533)**, number of leaves per plant and width of longest leaf (0.531)**. Also a high positive genetic correlation and a high error correlation between bulb weight and area of longest leaf were obtained (0.704)**

The genetic correlation between soluble solids and number of leaves per plant, length of longest leaf, and width of longest leaf were intermediate. These results suggest that genetic factors affecting these vegetative characters,

and environmental conditions of growth are of considerable importance among many other factors that influence bulb weight and soluble solids.

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