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RESEARCH ARTICLE

Genetically identification of Egyptian onion genotypes for seed yield under heat stress

El-Shaieny, A.A.H.* and A.M.A. Rashwan

Horticulture Department, Faculty of Agriculture, South Valley University, 83523 Qena, Egypt.

Abstract

Constraints are reported for the low productivity and quality of onion seed production in Upper Egypt. Therefore, a field experiment was conducted to study the influence of planting date and genotypes on yield and quality of onion seed production under Upper Egypt conditions where high average day /night-time of temperatures (27.4℃ and 11.2℃) for two seasons. The results revealed significant interactions between planting date and genotypes on seed yield/plant in both seasons and the number of umbel/plant in the 2nd season. The highest seed yield (442.25 kg/fed^{-1}) was recorded from Giza 20 planted in Early November sowing. Planted onion bulb set early- November increased seed yield (by 9.6% -17.9 % kg/fed) than grown early December. As a result, Giza 20 cultivar in early November in the current study area and other similar agro-ecology areas could be suggested to produce a better seed yield of onion. A principal component analysis was performed to interpret the distance between the genotypes. The average inter-cluster distance was found maximum (154.15) between G1 (Sabeeni) and G4 (Giza 20). The differences between the behavior of the seven studied traits in Giza 6 and Giza Red (Group I) are very weak, while for Sabeeni (Group III) and Shandaweel 1 (Group IV), the extent of the differences between the average traits reaches 26.5 % and 29.2% in 1st and 2nd planting dates under the conditions of Upper Egypt, thus considered 2 groups. The inter-seasonal and intra- seasonal fluctuation in both climatic parameters greatly affected the studied onion traits.

Keywords: Genotypes; Onion sets; PCA; Planting time; Seed yield.

1. Introduction

Onion *Allium cepa*, L. is considered one of the most exported vegetable crops widely cultivated in Egypt and all over the world. Due to Egypt is regarded as one of the leading countries in the production of onion, it is sought after in European markets and other countries in the world. Onions are compatible with Egypt's environmental and climatic conditions. The total onions cultivated area in 2018 was 185.30 with an average production of 14.79 tons (The Yearly Book of Economics and Statistics of the Ministry of Agriculture and Land Reclamation, Egypt, 2019). Successful onion seed production depends on selecting cultivars that are adapted to the different conditions imposed by different environments. Thus, assessments of the genotypes depend either on morphological, agronomic or physical and chemical measurements. Wide variations in the characteristics of the bulb were observed among the genotypes transplanted by several workers. Onions are sensitive to heat stress during their lifecycle, particularly during the reproductive phase. Fluctuations in the climate (whether it is an increase in the difference between day and night temperatures or between days, that is, thermal fluctuations variations), and occasionally increased humidity, whether free or ground, or air humidity, cold winds once and wet times lead to many flowers fall, which affects the final yield (Zinn *et al.*, 2010; Bueckert *et al.*, 2015). High temperatures may have reduced onion seed yield by increasing the

***Corresponding author:** **Abdel-Haleem A. H. El-Shaieny**
Email: a.elshaieny@agr.svu.edu.eg
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respiration rate, decreasing the concentration of nutrients, or reducing translocation of materials into the floral parts and seeds. Other factors, i.e., genetic expression, mineral nutrition, pathogenicity of organisms, or cell growth may have also influenced the yield. Therefore, ovule failure can probably result from a number of causes. However, due to the condition's complexity in a natural environment, identifying these causes is frequently impossible (Driedonks *et al.,* 2016). Thus, environmental conditions during growth and development have a significant impact on onion seed yield and quality. Furthermore, planting onion for seed yield in early-November resulted in the highest significant increases in number of scapes per plant, scape diameter, main scape length, umbel diameter, seed yield per plant, total seed yield per Fed^{-1}., and weight of 1000-seeds (El-Helaly and Karam, 2012). In addition, Farghali (1995) suggested that planting onion mother bulb on the beginning of September produced the highest seed yield and seed thousand weight. Late planting in January was associated with a lower number of seed stalks/plant, fewer capsules/umbel, the highest percentage of seed setting, and a lower seed yield (Mostafa, 1983). On the other hand, the average number of umbels/plant were not significantly affected by planting date whereas, early planting produced the largest umbel diameter, and the highest seed yield per plant (Ibrahim *et al.*, 1996; Malik *et al.,* 1999; Mosleh, 2008; Khodadadi, 2009). In opposite, Khodadadi (2009) reported that late planting date had a positive effect on onion seed production in Oman. Harvesting time of the onion seed crop is complicated by an asynchronous pattern of seed growth and development within and between umbels. Seeds have a proclivity to shed shortly after physiological maturity. So, the optimal harvest time should balance the rise in the number of physiologically mature seeds in umbels with the decrease in seed number caused by capsule dehiscence over time (Badawi *et al.*, 2010). In Italy, Amalfitano *et al.* (2019). reported that planting onion on the period of the end of December to mid-January was record the highest seed yield per hectare. Furthermore, the harvesting time should begin when nearly 25% of the capsules have unfold (Neal and Ellerbrock, 1986). When 1.5% open capsules are observed in the field, it is recommended that onion seed be harvested. Since the seed has reached maximum weight, full maturation, high viability, and vigor at this stage (El-Emery, 1993). As mentioned, the harvesting time is considered more sensitive for seed yield in onion crop, and that had a highly associated with planting date. The current study aimed to determine the most profitable planting date to greatly increase the seed yield of five onion cultivars under the agro-climatic conditions of Qena Governorate.

2. Materials and methods

The present study was conducted at the research experimental farm of the Faculty of Agriculture, South Valley University, Qena Governorate, during the two winter successive seasons of 2020/2021 and 2021/2022. The materials used in this study consist of combinations of five onion cultivars, namely Sabeeni, Giza 6 Improved, Giza Red, Giza 20 and Shandawel 1, with the two different planting dates. The soil of the experimental site was sandy. The bulb sets were selected and planted in the field on 5th November and 5th of December during both 2020/2021 and 2021/2022 seasons at 30 cm apart on rows. Each experimental unit was 12.25 m2 and contain five rows, each 3.5 m long and 0.7 m wide.

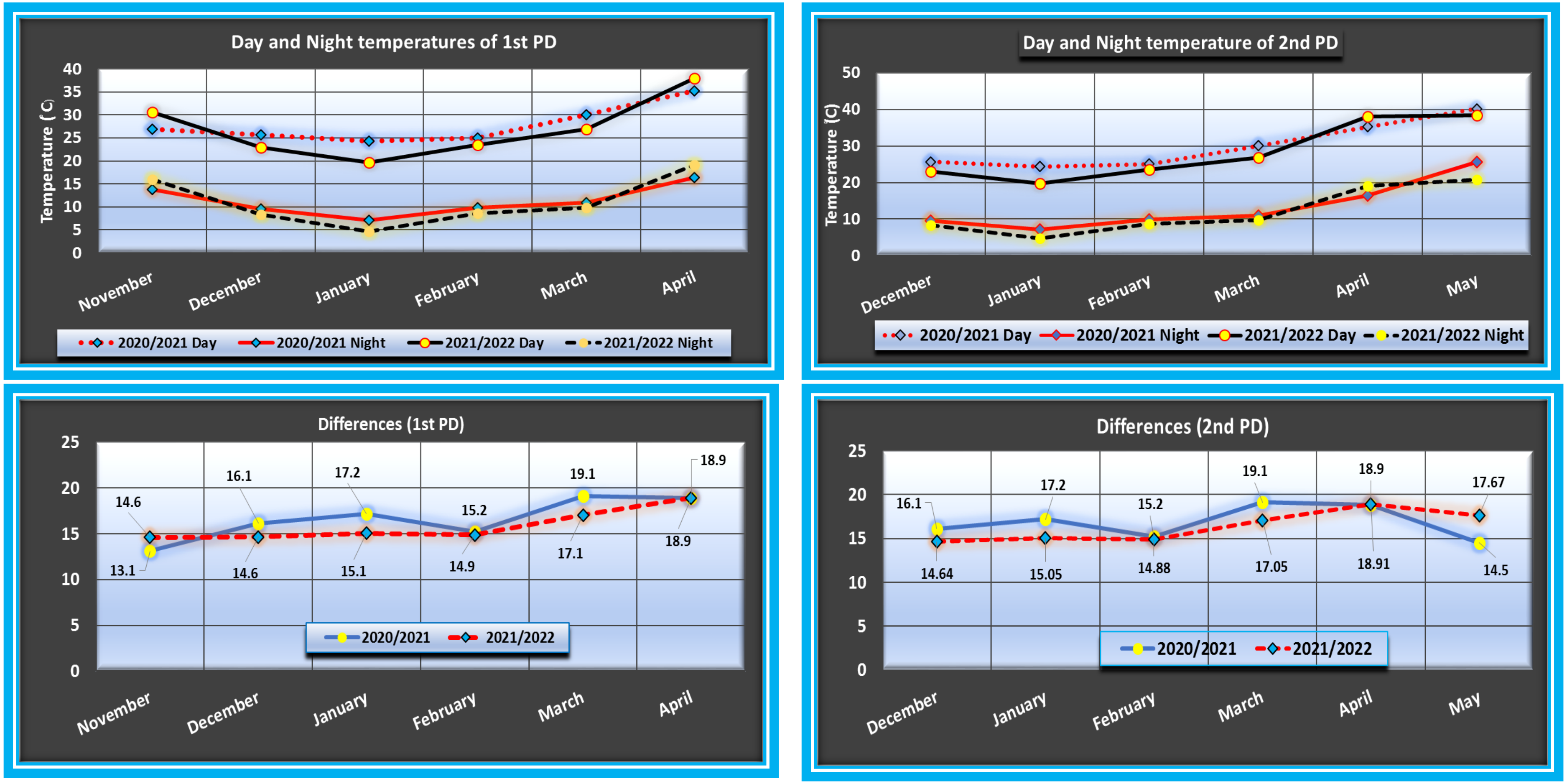

Fig. 1. Average of monthly Day- and Night-Time temperatures of 1st planting date (PD) (Top) as well as the differences between Day- and Night-Time (Down) during 2020/2021 and 2021/2022 seasons.

The experiment was designed as a split plot with three replications. The main plots were assigned to the two planting dates, while the five onion cultivars were assigned to sub plots.

Recommended cultural procedures other than the applied treatments were followed. Monthly Day and Night-Time means of temperatures at Qena Governorate during for two planting dates in both 2020/2021 and 2021/2022 seasons are shown in the Fig. 1.

2.1. Data collection

A random sample of 5 plants was taken from each plot for record the following data: After 100 days after planting (DAP), both plant height (PH, cm) and number of leaves/plant (NL) were measured, while the number (UN) and diameter (UD) of the Umbel were recorded at 150 DAP. After harvesting, measurements of the seed yield per plant (SYP, g) and 1000-seeds weight (1000-SW, g) as well as the total seed yield (TSY, kg) was estimated by converting the seed yield/plant (g) to seed yield (Kg/feddan).

2.2. Statistical Analysis

Data obtained during the two seasons of the study were statistically analyzed and treatments means were compared using the Duncan's multiple range tests according to Gomez and Gomez (1984).

3. Results and discussion

The investigation was conducted using 5 genotypes to evaluate their performance under Upper Egypt conditions where high average day/night-time of temperature (27.4℃ and 11.2℃) of two seasons (Fig.1). The analyses of variance for all studied traits revealed that mean squares of genotypes (Table 1) were highly significant, indicating the wide range of diversity among genotypes under the conditions of Upper Egypt.

In this respect, many authors found wide variability among onion cultivars for most of studied characters (Gamie *et al*., 2000; El-Damarany and Obiadalla-Ali, 2005; Gamie and Yaso, 2007; Marey and Morsy, 2010) under Upper Egypt conditions. The main effect of sowing dates (Fig. 3) was significant in both years for all studied traits in which D1 (5^{th} November) resulted the best values. These results are in agreement with those reported by Mostafa (1983), Amin and Rahim (1995) and El-Helaly and Karam (2012).

The studied traits were sensitive to high temperature and genotypes greatly varied in the sensitive levels. Genotypes differed significantly on yield, environment differences also contributed to these differences, because they cause the genotypes to perform differently when they are grown under different environments (El-Shaieny and Bashandy, 2022). Meteorological data viz., air temperatures and relative humidity during the growing seasons indicated that the 2020/2021 growing season was characterized by temperatures higher by about 0.93 and 0.18 ˚C in Day-Time and Night-Time, respectively in 1^{st} Planting date (D1) as well as 1.84 ˚C and 1.36 ˚C, respectively in 2^{nd} planting date (D2) comparing with the 2^{nd} season. Warmer air temperature dominated the first season were accompanied by generally higher relative humidity as in Figs. 1&2. However, the climatic features showed some exceptions during various growth periods. These inter-seasonal and intra- seasonal fluctuation in both climatic parameters greatly affected the studied onion traits. Biabani *et al.*, (2008) and Khalil *et al.*, (2011), stressed the effects of climatic change on seed yield and related components. Moreover, Mathew *et al.*, (2000) pointed out that cultural practices along with seasonal variations affect the growth and yield components.

The performance of genotypes at D1 (Fig. 3) was better compared to that of the other planting date (December planting), because of the differences in weather, origin geographical location were other factors that physiologically varied the performance of genotypes across the experimental site.

Table 1. Means of genotypes and analysis of variance for all studied traits in both planting dates of the two seasons

Item		Sabeeni	Giza 6	Giza Red	Giza 20	Shandawel 1	F. test G*D
				2020/2021			
PH	Early	64.89e	81.31ab	85.09a	83.75ab	78.25bc	NS
	Late	55.23f	70.91de	71.50cde	72.97cd	69.22de	
NL	Early	7.94c	10.14a	9.84a	9.56a	8.79b	NS
	Late	5.57e	7.86c	7.08d	6.94d	6.43d	
UN	Early	3.51c	4.36ab	4.20b	4.73a	3.41c	NS
	Late	2.77d	3.18c	3.24c	3.30c	2.63d	
UD	Early	5.18de	6.76c	7.18b	7.46a	5.10de	NS
	Late	3.75f	4.83e	5.25d	5.44d	3.15g	
SYP	Early	17.35c	21.13b	22.05b	25.11a	17.79c	**
	Late	9.64e	12.63d	12.48d	13.00d	9.83e	
TSY	Early	351.8d	422.65bc	440.90b	502.25a	355.80d	NS
	Late	219.75f	302.60e	349.50d	403.00c	233.10f	
1000-SW	Early	4.50ab	4.28bcd	4.11de	4.64a	4.07de	NS
	Late	4.18cde	3.94e	3.90e	4.41abc	3.92e	
				2021/2022			
PH	Early	91.65b	94.28a	93.52a	93.55a	90.50c	NS
	Late	87.62d	89.91c	90.03c	88.18d	85.63e	
NL	Early	9.28c	11.51a	11.19a	10.93a	10.11b	NS
	Late	6.95f	9.16cd	8.56de	8.28e	8.02e	
UN	Early	9.28c	11.51a	11.19a	10.93a	10.11b	**
	Late	6.95f	9.16cd	8.56de	8.28e	8.02e	
UD	Early	9.28c	11.51a	11.19a	10.93a	10.11b	NS
	Late	6.95f	9.16cd	8.56de	8.28e	8.02e	
SYP	Early	19.69c	23.47b	24.39b	27.45a	20.13c	**
	Late	13.40f	14.95d	14.70de	15.26d	13.81ef	
TSY	Early	393.75c	469.45 b	487.70 b	549.1a	402.60c	NS
	Late	232.95fg	269.00ef	273.90e	335.25d	231.20g	
1000-SW	Early	4.58ab	4.34bc	4.19c	4.72a	4.15c	NS
	Late	3.48d	3.43de	3.14ef	3.44de	3.06f	

PH; plant height; NL: number of leaves/plant; UN: number of umbel/plant; UD umbel diameter; SYP: seed yield/plant; TSY: total seed yield and 1000 SW: weight of 1000 seeds. NS and **, not significant and significant at ($p \leq 0.05$), respectively. Means followed by different letter are significantly different at 5% level of significance

Therefore, environment played a major role in influencing the performance of genotypes evaluated across both planting dates. It was believed that these are the main factors that contributed to the difference in performance of these genotypes across the planting dates.

In the combined data, there were differences for PH, NL, UN and UD among the evaluated genotypes (Fig. 4) which implies that the environment plays a major role in influencing the performance of genotypes. Hence, under favorable conditions (such as adequate moisture, good nutrient availability and ideal temperature), a plant can be producing more branches.

Right genotypes were good at all the planting dates of both seasons, with the exception of Sabeeni and Shandaweel-1 in most traits, this differential response may be permanent features for these genotypes. However, the performance of genotypes was different due to differences in their genetic constitution, As Becker and Leon (1988) and Brancourt-Hulmel *et al.,* (1997), note genetic constitution, has a bearing on the extent of G × E interaction.

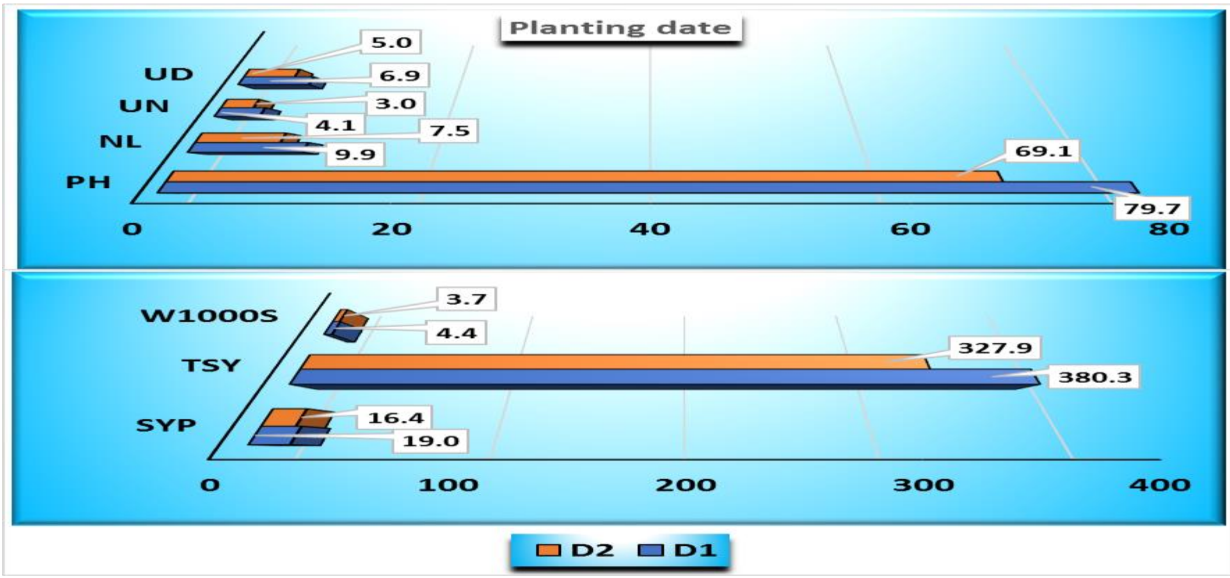

Fig. 3. PH, NL, UN, UD, SYP, TSY and 1000-SW of onion plants as affected by 1st (D1) and 2nd (D2) planting date during the two studied years.

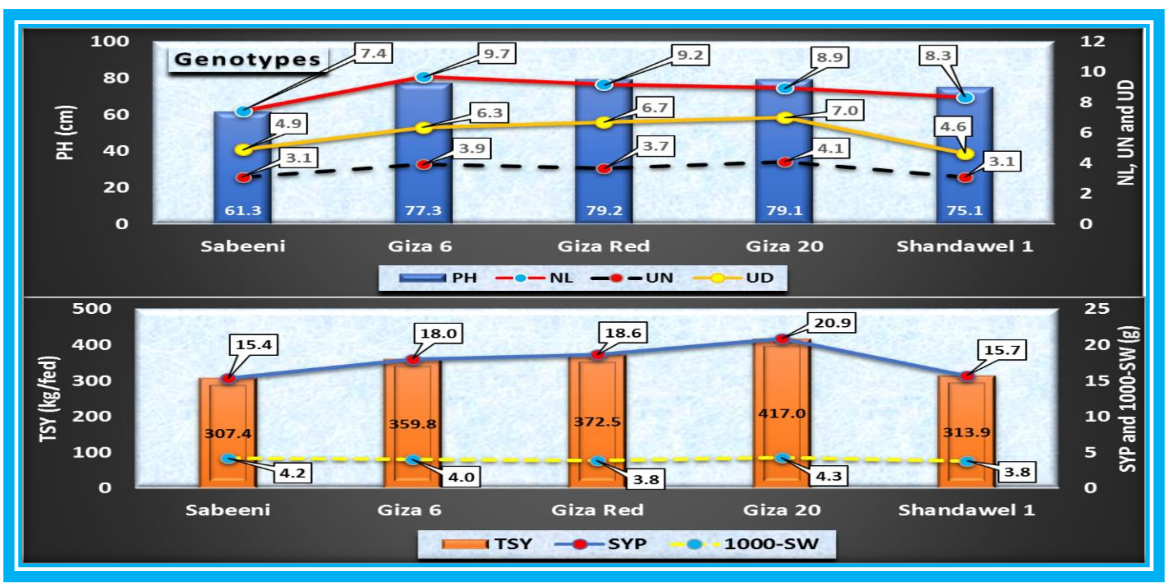

Fig. 4. PH, NL, UN, UD, SYP, TSY and 1000-SW of onion plants as affected by five genotypes during the two studied years.

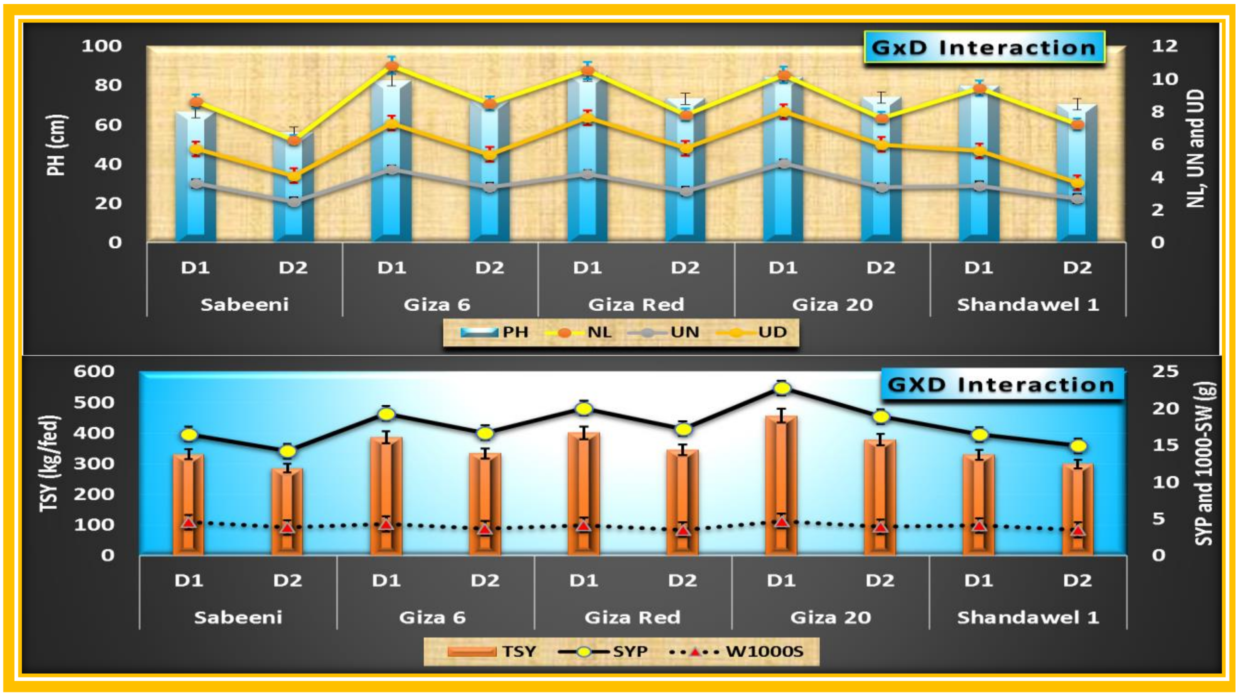

Fig. 5. PH, NL, UN, UD, SYP, TSY and 1000-SW of onion plants as affected by genotypes interacted with 1st (D1) and 2nd (D2) planting date during in average of both seasons.

3.1. Cluster analysis and genetic distance

The results of the PCA of the genotypes of onion are presented in Table 2. The principal component analysis revealed that four principal components PC1, PC2, PC3 and PC4 with eigenvalues 5.24, 1.52, 0.17 and 0.07 respectively in 1st planting date and 5.08, 1.47, 0.28 and 0.17, respectively in 2nd planting date have accounted for 100% of the total cumulative variability among genotypes. The first two principal components PC1 (74.9 & 72.6%) and PC2 (21.8 & 21.0%) showed eigenvalues more than one and cumulatively they explained 96.7 and 93.6 % variability for 1st and 2nd planting date, respectively, *i.e.* the highest variance when correlating the most relevant components. The contribution of PC1 towards variability was highest (74.9% and 72.6%) in both planting dates. The results showed that UD & UN in PC1 and UN & PH in PC2 had the highest loadings in both planting dates. Pradhan *et al.* (2011) reported that PCA for 12 traits out of these only the first two components in the PCA analysis had Eigen values up to 1.0, presenting cumulative variance of 84.1%.

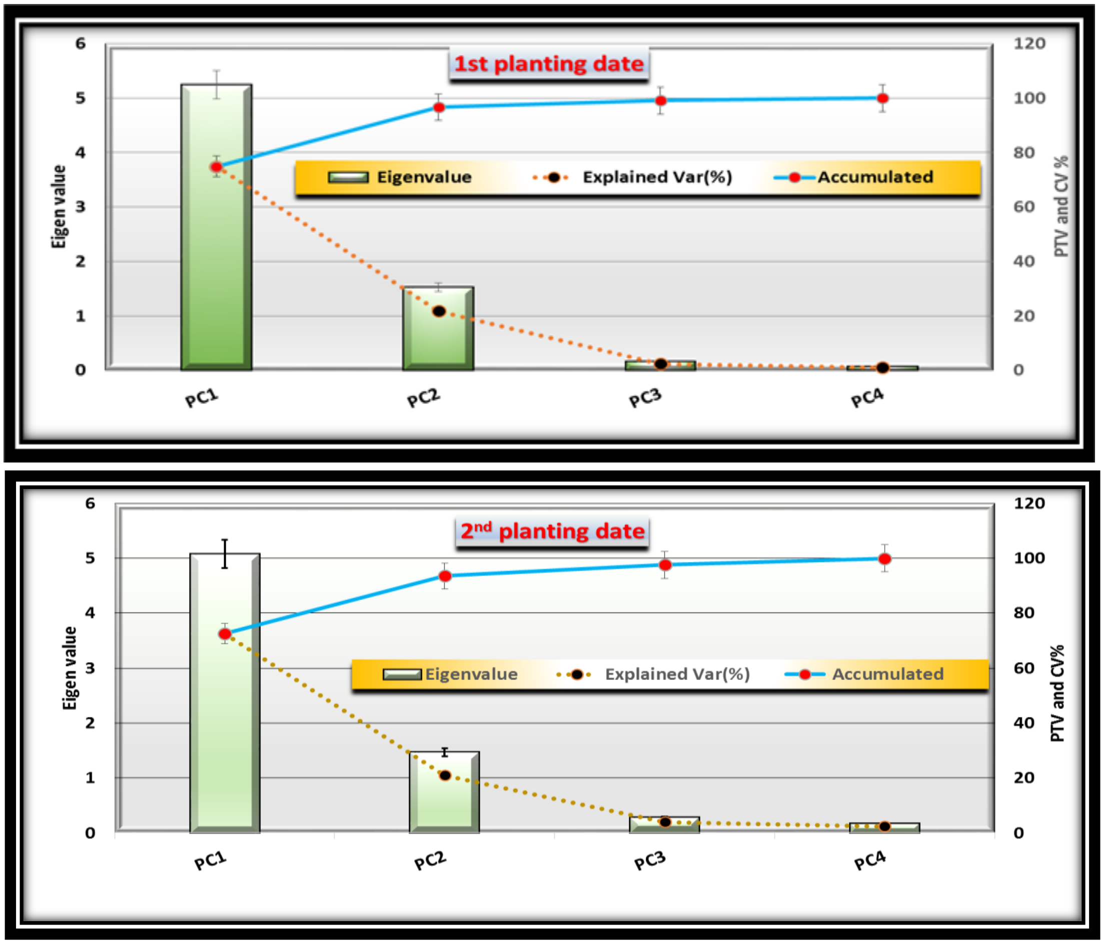

Fig. 6. Scree plot of Eigen values, variability proportion and cumulative variability (%) for studied traits of five onion genotypes in 1st (Up) and 2nd (Down) planting dates

Table 2. Principal component analysis for different traits in onion genotypes.

Variables	PC of genotypes			
	PC1	PC2	PC3	PC4
		1st planting date		
PH	0.358	0.374	0.418	0.429
NL	0.425	0.365	-0.191	-0.027
UN	-0.478	0.609	0.390	0.147
UD	-0.484	-0.215	-0.268	0.695
SYP	0.476	-0.166	-0.094	0.557
TSY	-0.476	0.166	0.094	-0.557
W1000S	0.476	-0.166	-0.094	0.557
		2nd planting date		
PH	0.373	0.375	0.437	0.412
NL	0.362	0.354	-0.009	-0.203
UN	-0.414	0.601	0.309	-0.109
UD	-0.554	-0.089	-0.094	0.671
SYP	0.374	0.288	-0.594	0.470
TSY	-0.308	-0.350	0.428	-0.503
1000-SW	0.308	0.350	-0.428	0.503

The first PC has positive association with SYP and 1000-SW, while negative association with TSY, UD and UN in both planting dates. The second PC has positive association with UN and NL in both planting dates as well as TSY in 1st planting date and both SYP and 1000-SW in 2nd planting date, while negative association with UD, SYP and 1000-SW in 1st planting date and TSY in 2nd planting date. The third PC has positive association with UN in both planting dates and TSY in 2nd planting date, while negative association with UD and NL in 1st planting date and both SYP and 1000-SW in 2nd planting date. The fourth PC has positive association with UD, SYP, 1000-SW in both planting dates and UN in 1st date, while negative association with TSY in both dates as well as both NL and UN in the 2nd planting date.

A principal component analysis was performed to interpret the distance between the genotypes. Again, Fig. 4, revealed scattered diagram of genotypic distribution pattern on axis. Interestingly, distribution of genotypes along the two axes in the PCA plot was consistent with the grouping of these genotypes obtained using cluster analysis. The Scree plot indicates most of the variation is derived the first and second components in the Eigenvalue of the genotypes data. The results obtained from biplot-PCA indicated the presence of high genetic variations among genotypes based on the data of 7 studied traits (Fig.8). Two genotypes were classified in first cluster accounting 40 per cent of total genotypes beside three other clusters having one genotype in each cluster. G4 (Giza 20) was found to be much distanced genetically from other genotypes, followed by G1 (Sabeeni) and G5 (Shandaweel1) that distanced from the rest of genotypes under study. The other two genotypes (Giza 6 improved and Giza Red) were scattered over the plot with a lower genetic distance. The close distance between these genotypes and their framing within a group corporation may be due to the presence of common progenitors (Mohamed and Adel, 2012; Tahir *et al.*, 2021). The high genetic variation among genotypes results in allelic amplitude that may represent their characteristics in the population. This variation levels may be due to geographic pattern, different pedigrees, characteristics and growth performance.

Pairwise comparisons were made between all genotypes and the mean dissimilarity values were calculated based on the studied 7 traits of onion. The distance between all five onion genotypes was estimated. The dissimilarity coefficient ranged from 14.9 (between G1 and G5) to 154.14 (between G1 and G4), as shown in Table 3. So, average inter-cluster distance was found maximum (154.15) between G1 (Sabeeni) and G4 (Giza 20). This range of difference indicates a reasonable variation between the genotypes under study.

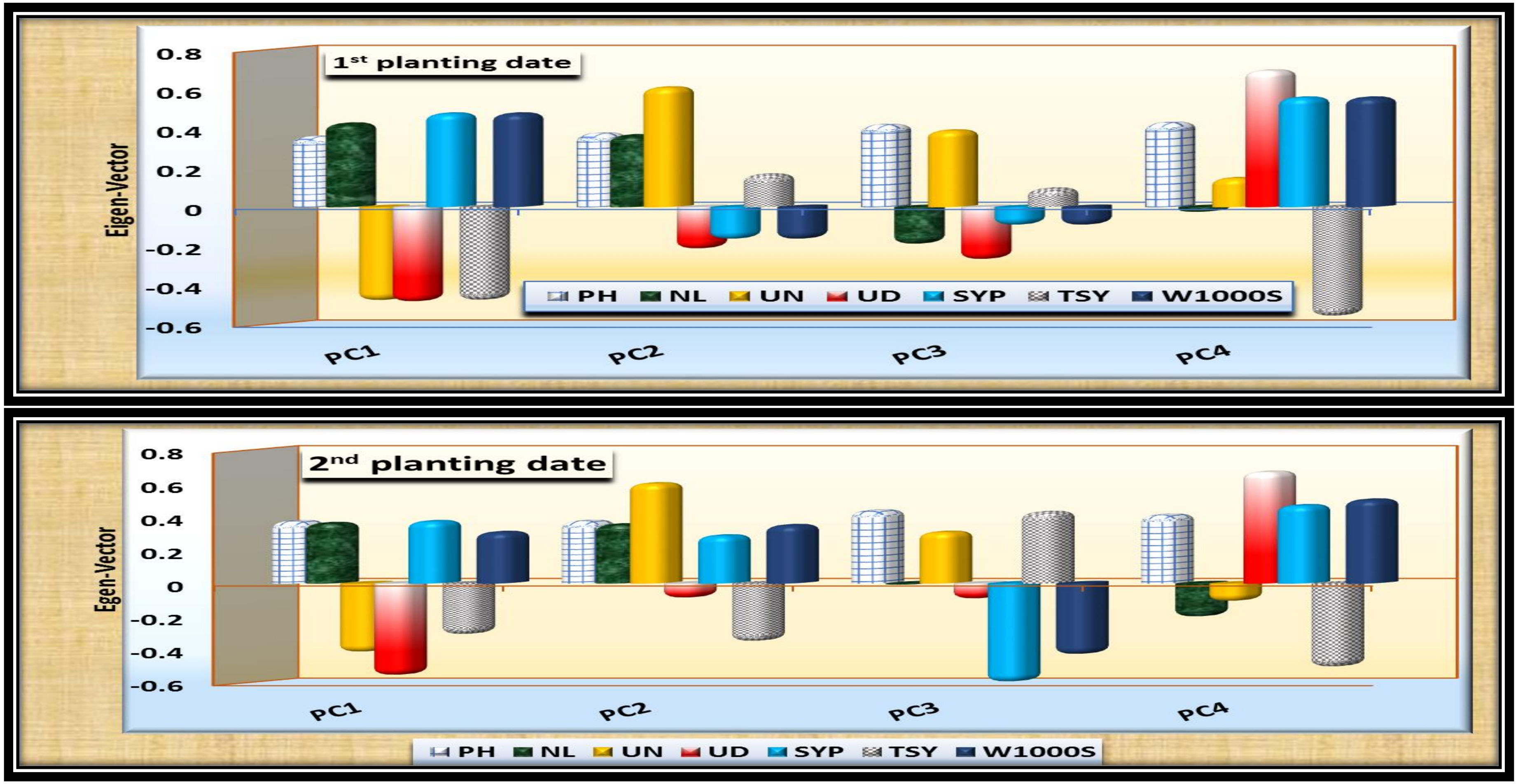

Fig. 7. Scree plot of Eigen vector for studied traits of five onion genotypes

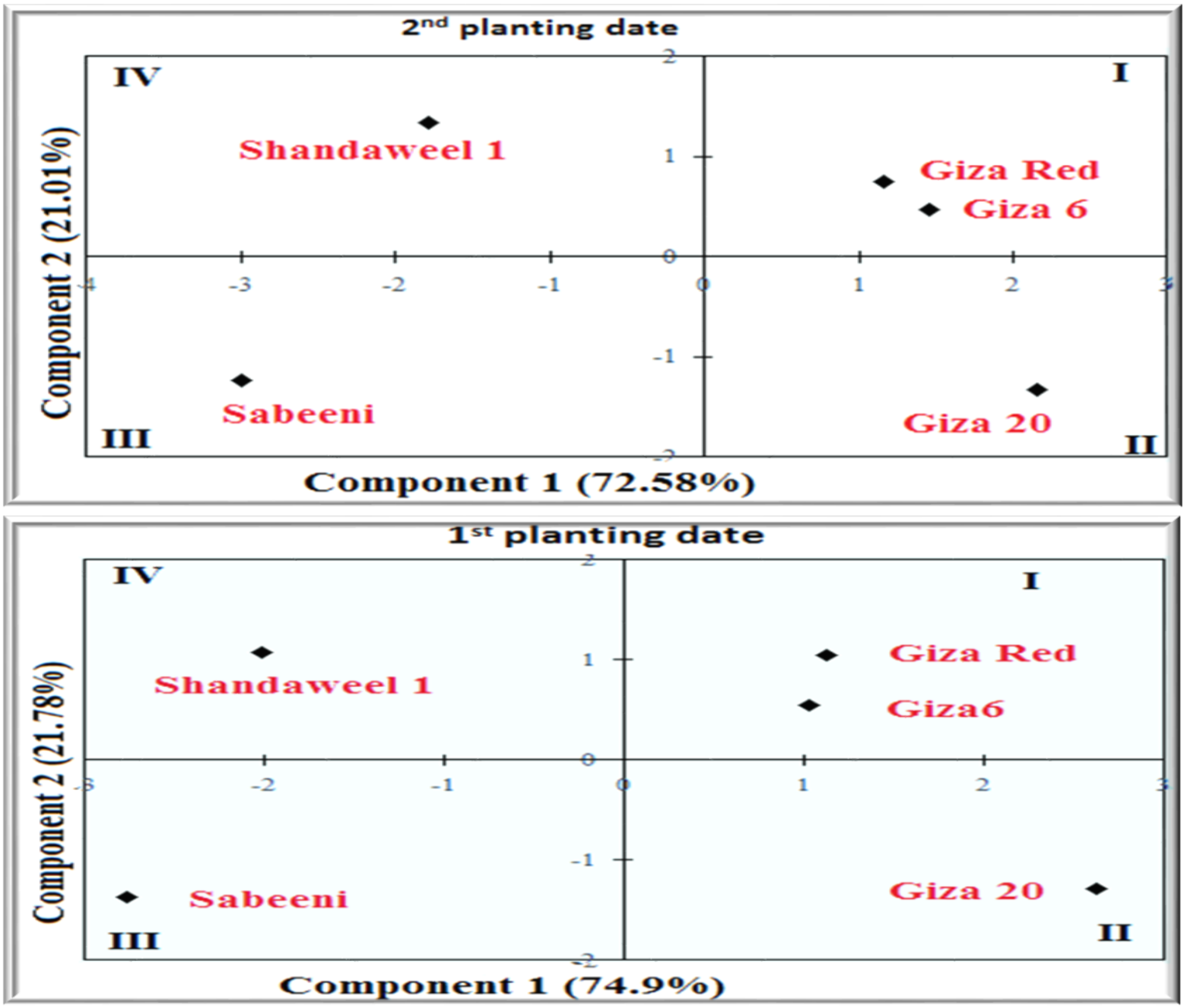

Fig. 8. Scattered diagram: Principal component analysis based on first and second components for the 5 onion genotypes, *i.e.*, Group I (Y1 >= 0, Y2 >= 0); Group II (Y1 >= 0, Y2 < 0): Group III (Y1 < 0, Y2 < 0) and Group IV (Y1 < 0, Y2 >= 0) for 1st (Top) and 2nd (Dawon) planting dates.

Table 3. Euclidean distance among five onion genotypes.

	G1	G2	G3	G4	G5
G1	0	75.233	93.587	154.148	14.9
G2		0	18.466	79.726	67.14
G3			0	61.441	85.455
G4				0	146.759
G5					0

Hybridization program may be reasonable if it is conducted between G1 and G4 and between G4 and G5 due to the high observed distances to obtain higher heterosis value for important characteristics, and also relieve the hastiness of primitive extinction and adaptive genes among the studied genotypes (Govindarajan *et al.*, 2015). The small distances between G1 and G5 could have corresponded to their origination from a common ancestor or some genetic materials might be replaced among parental roots of these genotypes, which makes them combined into one main group *(Tahir et al., 2021).*

3.2. UPGMA clustering dendrogram

Figure 9 exhibits the UPGMA dendrogram generated by the cluster analysis based on 7 phenotypic traits of onion cultivars.

In general, it shows two large Categories, named A (High in most traits) and B (Low in most traits). In a harsh selection, via the adopted severance point, five groups were formed, three of which were within Category A that considered only two groups (I & II) due to the great genetic similarity (81.5) between Giza Red and Giza 6 (Group I) and two within Category B (III & IV).

The differences between the behavior of the seven studied traits in Giza 6 and Giza Red (Group I) are very weak, while for Sabeeni (Group III) and Shandaweel 1 (Group IV), the extent of the differences between the average traits reaches 26.5 % and 29.2% in 1st and 2nd planting dates under the conditions of Upper Egypt, thus considered 2 groups.

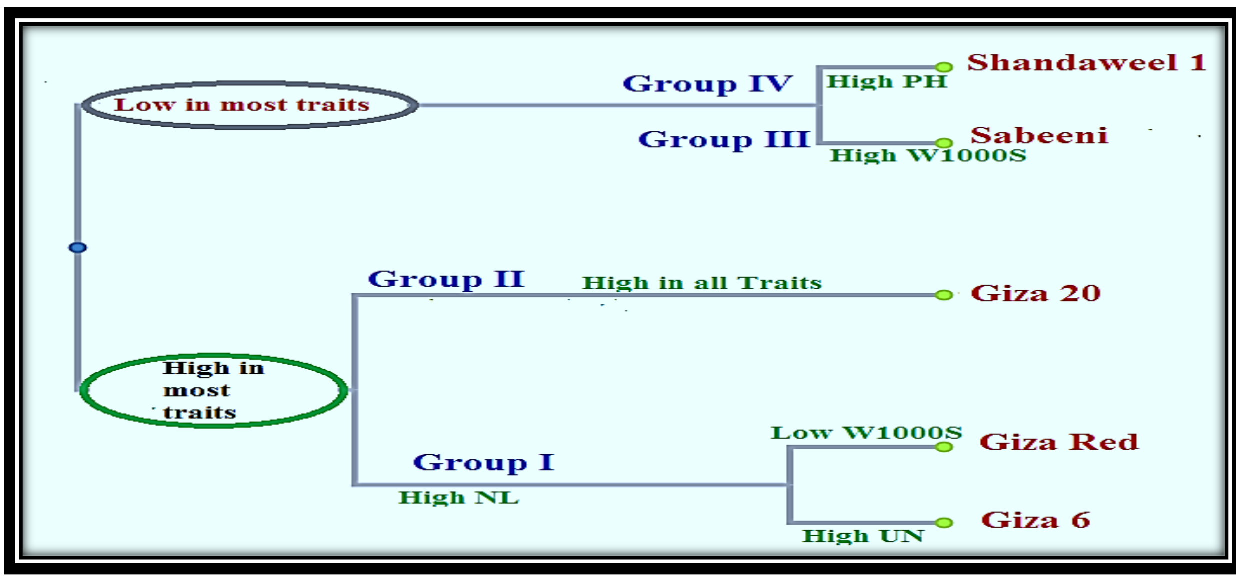

Fig. 9. Dendrogram, using average linkage (Between Groups), for five onion genotypes based on all studied traits.

Interestingly, distribution of genotypes through dendrogram was consistent with the grouping of these genotypes obtained using cluster analysis and along the two axes in the PCA plot (Fig. 8).

Again, Fig. 8, revealed scattered diagram of genotypic distribution pattern on axis. Interestingly, distribution of genotypes along the two axes in the PCA plot was consistent with the grouping of these genotypes obtained using cluster analysis. The first PC (Table 4 and Fig.7) has positive association with SYP and 1000-SW, while negative association with TSY, UD and UN in both planting dates.

The second PC has positive association with UN and NL in both planting dates as well as TSY in 1st planting date and both SYP and 1000-SW in 2nd planting date, while negative association with UD, SYP and 1000-SW in 1st planting date and TSY in 2nd planting date. The third PC has positive association with UN in both planting dates and TSY in 2nd planting date, while negative association with UD and NL in 1st planting date and both SYP and 1000-SW in 2nd planting date. The fourth PC has positive association with UD, SYP, 1000-SW in both planting dates and UN in 1st date, while negative association with TSY in both dates as well as both NL and UN in the 2nd planting date.

Table 4. Traits that have a key role in analyzing genetic diversity and explaining total genetic variance in 5 onion genotypes at 1st and 2nd planting dates

	PH		NL		UN		UD		SYP		TSY		W1000S	
	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
PC1	+	+	+	+	-	-	-	-	+	+	-	-	+	+
PC2	+	+	+	+	+	+	-	n	-	+	+	-	-	+
PC3	+	+	-	n	+	+	-	n	n	-	n	+	n	-
PC4	+	+	n	-	+	-	+	+	+	+	-	-	+	+

+, -, n positive, negative and negligible association with PCs.

4. Conclusion

As a result, Giza 20 at early November in the current study area and other similar agro-ecology areas of the country can be recommended for the production of better seed yield and quality of onion. From obvious results, it can be concluded that in For future experiment, traits contributing maximum to genetic diversity such as UD, UN, SYP and plant height should be given top priority as selection parameters and diverse genotypes identified in the present study may be utilized for attempting heterotic cross combination and developing hybrid varieties.

Authors' Contributions
All authors are contributed in this research.

Funding
There is no fund in this research.

Institutional Review Board Statement
All Institutional Review Board Statement are confirmed and approved.

Data Availability Statement
Data presented in this study are available on fair request from the respective author.

Ethics Approval and Consent to Participate
This work carried out at Horticulture Department, Faculty of Agriculture, South Valley University and followed all the department Instructions.

Consent for Publication
Not applicable.

Conflicts of Interest
Declare no conflict of interest.

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