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Evaluation of some Sugar Beet Varieties under Drought stress using Meta-analysis I- Yield and Related Traits

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ABSTRACT: The current study's goals were to investigate the physiological responses and to evaluate agronomic characters and sugar related characters in fifteen sugar beet varieties using AMMI and principal components biplot to find drought-tolerant sugar beet varieties under drought conditions, screen sugar beet varieties with high yield potential, then assess the degree of relationship among the different traits. Two experiments was conducted at a privet farm in Moghra Region, South of Alamein, Matrouh Governorate, Egypt (latitude of 30° 11' 58.13˝ N and longitude of 28° 59' 21.05˝E) in 2021/2022 and 2022/2023 seasons. Results showed that sucrose %, purity%, Leaf area index, impurities, leaf relative water content, root yield, sugar yield, varied significantly among varieties under drought conditions. Also, significant differences among varieties for traits% were detected in all treatments during both seasons. Concerning proline concentration, the results shown that proline concentration was higher and significantly increased by decreasing IWR from 100% to 60% of the IWR in both seasons. In addition, the first two interaction principal components (IPCA1 and IPCA2) for proline accounted jointly for 96.67% of the variation caused by interaction. Results showed highly significant and positive correlation between root yield, Water use efficiency of root yield and impurities, followed by root yield and Leaf area index then root yield and proline while root yield negative correlation with purity%. In contrast, high positive correlation between sugar yield and proline, followed by proline and sucrose %.

Keywords: Sugar beet, Water use efficiency, Leaf area index principal components, AMMI and proline

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INTRODUCTION

Sugar beet is a member of the chenopodiaceae family and is regarded as a salt-tolerant crop. This deep-rooted plant exhibits a high level of resistance for water stress situations like salt and drought (Brar et al 2015). Consequently, this plant might be a useful resource for researching processes of drought tolerance. Abiotic stresses such as extreme temperatures, drought and salinity are the most damaging factors affecting the growing and production of crops global (Gao et al. 2007; Fujita et al. 2014). Abiotic stresses caused about 70% of productivity losses (Acquaah 2007). Soil salinization is increasing due to sea level rise, climate change, soil erosion and irrigation with saline water Nachshon (2018), and effects sugar beet yield negatively Taghizadegan et al (2019). While sugar beet is highly drought- and salt-tolerant plant (Niazi et al 1999, Pinheiro et al 2018 and Wisniewska et al 2019), both stress factors impinge yield loss in beet production and cause growth retardation (Romano et al 2013, Khayamim et al 2014, Sakr et al 2014 et al., 2019). Additionally, plant breeders will be able to develop stress-resistant characters and spread the genetic variability in sugar beet thanks to the isolation of highly drought-and salt- tolerant beet cultivars (Niazi et al 1999, Skorupa et al 2019 and Islam el at 2020) and the ability of sugar beet to grow in reclaimed lands, which are negatively affected by salt, sodicity, and poor nutrient availability (Wang et al 2017, Deveci et al 2019 , and Abbasi 2020). When plants are subjected to different stressful conditions, proline, an amino acid, helps them feel less stressed (Gholami Zali and Ehsanzadeh, 2018).

Proline builds up in crops as they adjust to several environmental challenges, including drought, salinity and extreme temperature exposure (Oncel et al. 2000). The primary growth abiotic stress concerns will therefore be salinity and drought stress (Ram and Karuppaiyan 2018). Salinity, drought, and excessive temperature stress are the most harmful of them because they impair the metabolic functions of plants (Akula and Gokare 2011; Vishwakarma et al. 2017; and Rastogi et al. 2019). Salinity is frequently linked to the abscisic acid signalling pathway and may cause membrane damage or macromolecule breakdown through the production of ROS (Wang et al. 2003). According to Hasegawa et al. (2000), the causes of soil salinity's effects on growth, yield, and quality could be physiological dryness and ion toxicity, which results in metabolic toxicity, membrane disorganization, and the generation of reactive oxygen species (ROS).Importantly, salinity and drought also have significant negative effects on cellular energy supply and redox homeostasis, which are countered by a universal re-programming of plant main metabolism also altered cellular architecture (Chen et al., 2005; Baena-González et al., 2007, Jaspersand-Kangasjärvi, 2010, Miller et al., 2010).

In cultivar release programs, regression-based and multivariate statistical analyses are perhaps the most widely used techniques for evaluating yield stability. Numerous ways to include various genotype-environment interactions are offered by multivariate statistical analysis. The other most used statistical technique is the additive main effects and multiplicative interaction (AMMI) model (Gauch 1992). The structure of interactions between genotypes and environments can be comprehended by its application. The model's ability to distinguish between the primary interactions and explain a significant portion of the interaction's overall deviation accounts for its widespread application (Ebdon and Gauch 2002). Although only a small number of genotypes were utilized for stability analysis, the AMMI model was utilized for GEI analysis of sugar yield and content in sugar beet monogerm cultivars, and the results showed that genotype and environment had significant effects on these variables (Moradi and Jalilian 2012). On the other hand, AMMI can be utilized to comprehend how environments and genotypes interact. ANOVA and PCA are combined in AMMI analysis (Oroian et al 2023). Among the most popular multivariate techniques for GEI data processing and visualization is additive main effect and multiplicative interaction (AMMI) (Mehareb et al., 2023). In a single model, AMMI integrates principal component analysis (PCA) with analysis of variance (ANOVA) (Gauch, 2013). Common multivariate technique is PCA. Some studies have evaluated the characteristics of various sugar beetroot cultivars using PCA. Jia el al (2015)and Mehareb et al 2021. Employed correlation PCA techniques for the amounts of eleven elements, such as salt and potassium, to thoroughly assess the quality of thirty-four varieties of sugar beetroot from five distinct producing locations. The comprehensive analysis and assessment of the amino acid composition of the roots of fourteen distinct varieties of sugar beets has also been conducted using the PCA method. Even yet, a number of recent research have concentrated on PCA analysis of the agronomic characteristics of sugar beetroot cultivars. Therefore, the goals of this investigation were: investigate the physiological responses and to evaluate agronomic characters and sugar related characters in fifteen sugar beet varieties using META – analysis (AMMI biplot and PCA) and screen sugar beet varieties with high yield potential, then assess the degree of relationship among the different traits.

MATERIALS AND METHODS

This study was conducted at a privet farm in Moghra Region, South of Alamein, Matrouh Governorate, Egypt (latitude of 30° 11' 58.13˝ N and longitude of 28° 59' 21.05˝E) in 2021/2022 and 2022/2023 seasons to evaluate fifteen sugar beet varieties under the effect of high water salinity stress. This investigation included forty-five treatments represented the combination among three irrigation levels (60%, 80% and 100% of the calculated irrigation requirements) and fifteen varieties (polygerm varieties: Faten, Kwamera, Halawa, Dina, Raspoly, Belino and Kosmas, and mongerm varieties: Salama, Elmo, Cassiopeia, Sandor, Simada, Gusatve and Ribera). The randomized complete block design was used, in a split plot arrangement, with three replications, where irrigation water levels were allocated to the main plots and varieties were distributed at random in the sub plots. The area of each sub plot was 12 m^2, which included 5 ridges of 4-m in length and 60-cm apart with 20-cm between hills. Sugar beet varieties were sown in the first week of October in both seasons. Other culture practices treatments, were applied as recommended by the Sugar Crops Research Institute (SCRI) recommendation. Water and soil samples (0-60 cm depth) were collected from the experimental site to determine its physical and chemical properties using the methods described by Cottenie *et al.* (1982) as shown in (Tables 1 and 2). Agro/meteorological data at Moghra region are illustrated in (Table 3). Values of crop factor (K_c) through the growing seasons are shown in (Table 3). Table 4 exhibits the average amounts of water applied (m^3/fed) throughout the growing seasons for the three

Table 1. Physical and chemical characteristics of the experimental soil site

Physical characteristics								
Soil depth (cm)	**Particle size distribution%**			**Texture class**	**Bulk density (g/cm^3)**	**Moisture content by volume (%)**		
	Sand	**Silt**	**Clay**			**Field Capacity**	**Wilting Point**	**Available Water**
0-20	92.5	4.5	3.0	Sandy	1.95	16.25	6.50	8.75
20-40	93.0	5.2	1.8		1.77	15.32	5.80	10.35
40-60	94.5	4.0	1.5		1.62	15.00	5.70	10.90

Chemical characteristics											
Soil depth (cm)	**EC (dS/m)**	**p^H**	**SP**	**Soluble anions (meq/l)**				**Soluble cations (meq/l)**			
				CO_3^{--}	**HCO_3^-**	**Cl^-**	**SO_4^{--}**	**Ca^{++}**	**Mg^{++}**	**Na^+**	**K^+**
0 –20	3.76	8.20	20.0	0.20	1.42	9.32	34.47	30.30	6.06	6.06	8.00
20-40	2.51	8.20	20.0	0.10	1.45	2.65	9.99	6.82	2.36	3.96	0.59
40-60	1.85	7.97	20.0	0.10	1.35	2.30	10.23	6.72	2.39	3.95	0.85

Table 2. Chemical analysis of irrigation water.

p^H	**EC (dS/m)**	**Soluble anions (meq/l)**				**Soluble cations (meq/l)**				**SAR**
		CO_3^{--}	**HCO_3^-**	**Cl^-**	**SO_4^{--}**	**Ca^{++}**	**Mg^{++}**	**Na^+**	**K^+**	
6.88	9.27	0.1	3.50	83.0	27.71	15.40	23.40	71.90	0.51	16.32

Table 3. Crop factor (K_c) through the growing season of sugar beet.

Initial		**Crop development**		**Mid-season**		**Late-season**		**Total (days)**
Time (days)	K_c	Time (days)	K_c	Time (days)	K_c	Time (days)	K_c	
30	0.35	60	$0.35>K_c<1.2$	60	1.2	60	$1.2>K_c<0.7$	210

(FAO 33, 1979).

Table 4: Mean values of the amounts of the applied irrigation water requirements (IWR), (m^3/fed) throughout growing season drip irrigation systems.

Days from planting	**Growth stage**	**Amount of water (m^3/feddan*)**		
		60%	**80%**	**100%**
1 30	Initial	218.2	218.2	218.2
31 90	Development	294.1	392.2	490.2
91 150	Mid-season	405.8	541.1	676.4
151 210	Late-season	602.1	802.8	1003.6
Total in the season		1520.3	1954.4	2388.4

Feddan (fed) = 4200 m^2

studied irrigation treatments (Figure 1).

Calculation of irrigation water requirements

Irrigation water requirement was determined using Blany and Criddle (1962) method:

$$IR_c = \frac{\left[(ET_0 \times K_c) \times Dd\right]}{Es}$$

Where: IR_c = total actual irrigation water requirements (mm/intervals), ET_o = evapotranspiration (mm/day) was calculated according to CROPWAT program (Smith,

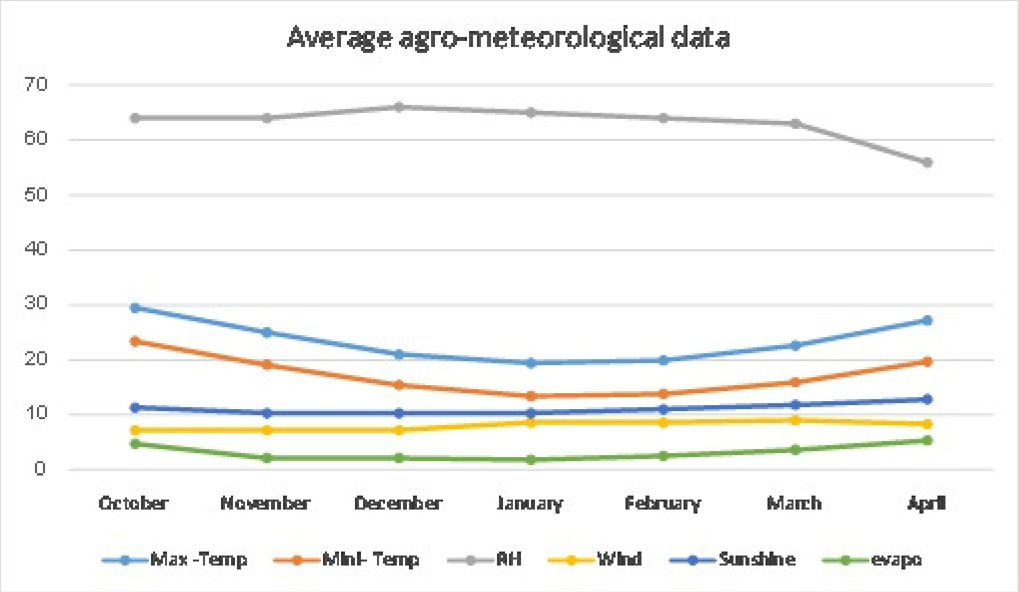

Figure 1. Average agro-meteorological data at Moghra region.
Source: Matrouh agro-meteorological station

1991), K_c = crop coefficient (Doorenbos and Kassam, 1979),

D_d = time intervals and E_s = system efficiency (%).

Studied characters

Growth traits

Plant samples were taken at 120 days after planting (DAP), each sample was separated into foliage and root to study leaf area. Leaf area measurement, the disk method was followed using 10 disks of 0.91 cm diameter according to Watson (1958). The following growth parameters were calculated:

Leaf area index (LAI) = leaf area per plant (cm^2) / Plant ground area (cm^2)

Biochemical analyses

After 120 days of planting, random samples were taken from each sub plot to determine the following:

Proline content was estimated by the ninhydrin method as cited by Bates *et al.* (1973).

Leaf relative water content (RWC %) was estimated according to the method of Weatherly (1950). Samples (0.5 g) of leaves were saturated in 100 ml distilled water for 24 h and their turgid weights were recorded. Then, they were oven-dried at 65°C for 48 h and their dry weights were recorded. RWC% was calculated as follows:

$$RWC\ \% = [(FW - DW) / (TW - DW)] \times 100$$

Where: FW, DW and TW are fresh, dry and turgid weights, respectively.

Quality parameters:

At harvesting (210 DAP), a sample of ten roots were taken at random from each sub plot cleaned and sent to Sugar Beet Laboratory at Nubaria Sugar Factory, El-Beheira Governorate, Egypt, to determine the following:

Sucrose percentage: was estimated by using sacharometer lead acetate extract of fresh macerated roots according to Carruthers and Oldfield (1960).

Juice impurities: in terms of Alpha amino nitrogen (α-amino N), Sodium (Na) and Potassium (K) concentrations according to the procedure of Sugar Company by Auto Analyzer as described by Cooke and Scott (1993), and calculated using the following formula**:** Juice impurities = 0.343 (K + Na) + 0.094 α-amino N +0.29.

Extractable sugar percentage (ES%): was estimated according to Reinefeld *et al.* (1974) by using the following formula:

ES% = pol - [0.343(K + Na) + 0.094 α-amino N + 0.29]. Where**:** Pol = sucrose percentage

Juice purity percentage = (ES% / pol) × 100

Harvesting took place in the last week of April at age of 210 days, where sugar beets from each plot were manually up-rooted, topped and weighed in kg, then converted to ton/fed to calculate root yield/fed. Sugars yield/fed (ton) was calculated according the following equation:

Sugar yield/fed (ton) = root yield/fed (ton) × (extractable sugar %)

Water use efficiency (WUE) , was determined according to Jensen (1983) as follows:

$$\mathrm{WUE} = \frac{\text{root/sugar yield/fed (kg)}}{\text{amount of water applied/fed (m}^3\text{)}} \quad \mathrm{kg/m^3}$$

Collected data were statistically analyzed as shown by Snedecor and Cochran (1989). Treatment means were compared were made using least significant difference (LSD) at 5% level of probability.

Principal component analysis (PCA)

The PCA technique, as described by Harman (1976), was used to extract the components.

Statistical analysis

Analyses of variance were separately carried out as a split plot arrangement for each of the six environments for the collected data as per (Gomez and Gomez 1984). The Means were compared by least significant difference test at 5% level of probability ($p < 0.05$) using GeneStat-18 software program. Stability analysis and varieties by interaction (G × T).The following stability measurements were performed on root and sugar yields under the six environments (3 irrigation treatments *two seasons).Moreover, AMMI (the additive main effects and multiplicative interaction model) (Romagosa and Fox 1993; Bassiony et al 2020, Mehareb et al 2021, 2022) was applied on the root yield and sugar yield. Then the variety main effect (Akcura and Kaya 2008) was used to visualize the G × E interaction. The AMMI stability value ASV is the distance from the coordinate point to the origin in a two dimensional plot of scores for interaction IPCA1 and IPCA2 (the first and second principal component analyses scores) in the additive means effect and multiplicative. Interaction model (Purchase 1997). As IPCA1 score gives more to the variety by environment interaction sum of squares, a weighted value is chosen. This was estimated for each variety and each environment giving to the relative contribution of IPCA1and IPCA2 as per (Purchase et al. 2000; Naroui Rad et al.2013).

RESULTS AND DISCUSSION

Results in (Figures 2-13) showed that sucrose%, purity%, LAI, impurities, leaf relative water content **(**RWC), root yield, sugar yield, Water use efficiency (WUE) root and WUE sugar varied significantly among varieties under drought conditions. Also, significant differences among varieties for traits% were detected in all treatments during both seasons. Data in Figures (2 and 4) show that sucrose and extractable sugar significantly increased by decreasing IWR from 100% to 60% of the IWR in both seasons. Four varieties; Faten, Salama, Raspoly and Elmo, which recorded 9.71%, 13.85%, 9.79% and 8.88% in the 1st and 10.75%, 13.79%, 12.26% and 9.49% in 2nd seasons, respectively compared to grand mean of all varieties under 60% IWR. On other hand, in (Figure 3), the highest significantly value of purity% recorded by Fatan variety under 60% and 80% of IWR and Salama variety under 80% of IWR in the 1st season and 60% plus 100% of IWR and Simada variety under 80% of IWR in 2nd season. Data in Figures (5 and 6) show that, leaf area index (LAI) and RWC significantly increased by increasing IWR from 60% to 100% of the IWR in both seasons. LAI varied significantly among varieties under all irrigation treatments in both seasons 2021/2022 and 2022/2023. Belino, Kosmas and Simada varieties recorded the highest values of LAI under 60%, 80% and 100% of IWR in the both seasons, respectively. While, the Simada and Faten varieties recorded the highest value of RWC under 60% and 100% IWR in both seasons. This results agreement with Masri *et al.* (2015) exposed that sugar beet with 75% of IWR recorded the highest significant sucrose, extractable sugar, purity percentages, leaf area index, and white sugar yield, while application of 100% of IWR gave the heaviest root weight, purity %, root yield.

Proline and leaf relative water content

Figure 6 indicates that leaf relative water content (RWC %) of varieties were significantly affected by IWR in both seasons. Concerning proline concentration, the results

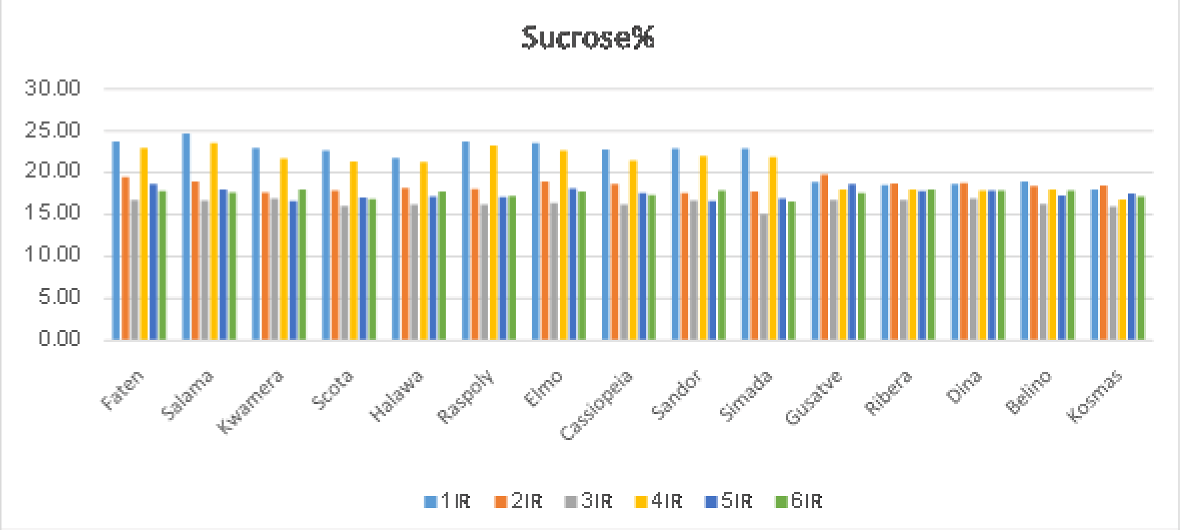

Figure 2: Sucrose % of sugar beet varieties as affected by different drought levels during 2021/2022 and 2022/2023 seasons. LSD = 1.893, 0.956 and 2.194 for drought levels, varieties and interaction, respectively in the first season and LSD= 1.905, 0.987 and 2.233for drought levels, varieties and interaction, respectively in the second season. **IR1 = 60%IWR, IR2 =80%IWR and IR3= 100%IWR in the first season, IR4 = 60%IWR, IR5 =80%IWR and IR6= 100%IWR in the second season.

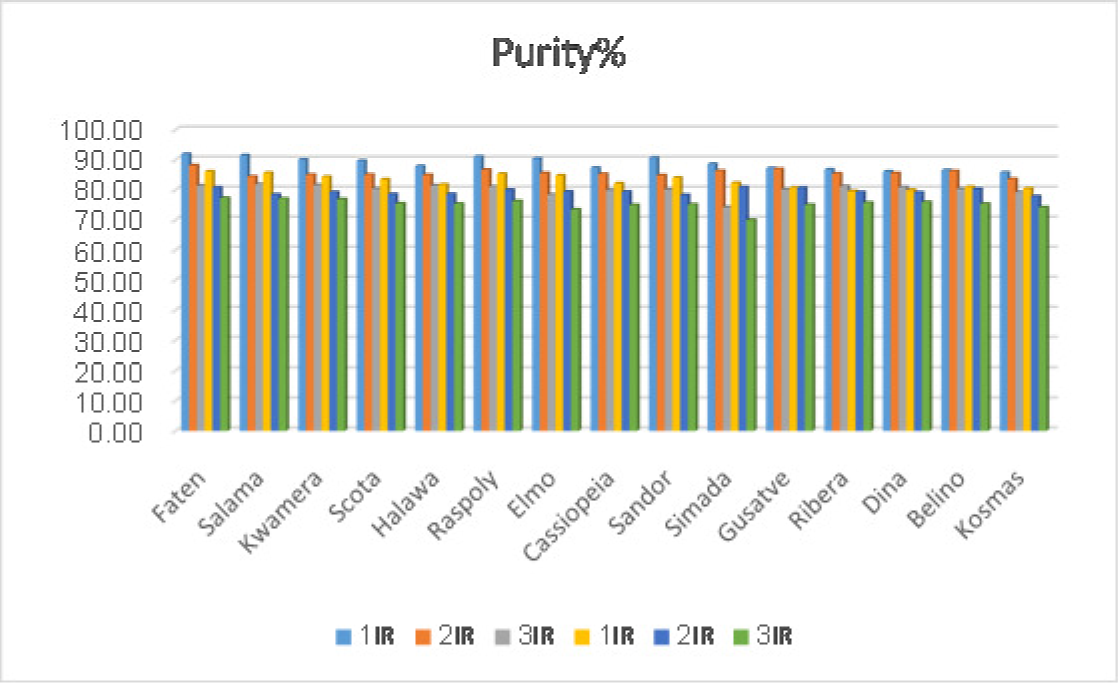

Figure 3: Purity % of sugar beet varieties as affected by different drought levels during 2021/2022 and 2022/2023 seasons. LSD = 3.897, 1.53 and 4.11for drought levels, varieties and interaction, respectively in the first season and LSD= 3.346 1.66 and 3.845 for drought levels, varieties and interaction, respectively in the second season. **IR1 = 60%IWR, IR2 =80%IWR and IR3= 100%IWR in the first season, IR4 = 60%IWR, IR5 =80%IWR and IR6= 100%IWR in the second season.

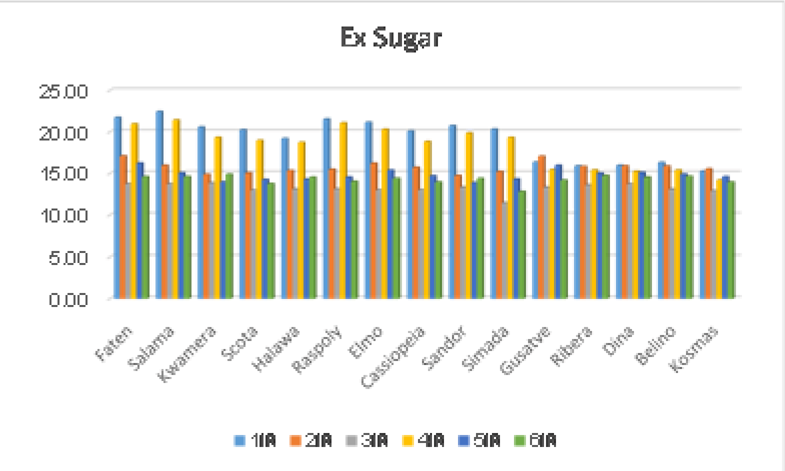

Figure 4: Extrable sugar% of sugar beet varieties as affected by different drought levels during 2021/2022 and 2022/2023 seasons. LSD = 2.2640.965 and 2.451for drought levels, varieties and interaction, respectively in the first season and LSD= 2.185, 0.996 and 2.423 for drought levels, varieties and interaction, respectively in the second season.
**IR1 = 60%IWR, IR2 =80%IWR and IR3= 100%IWR in the first season, IR4 = 60%IWR, IR5 =80%IWR and IR6= 100%IWR in the second season.

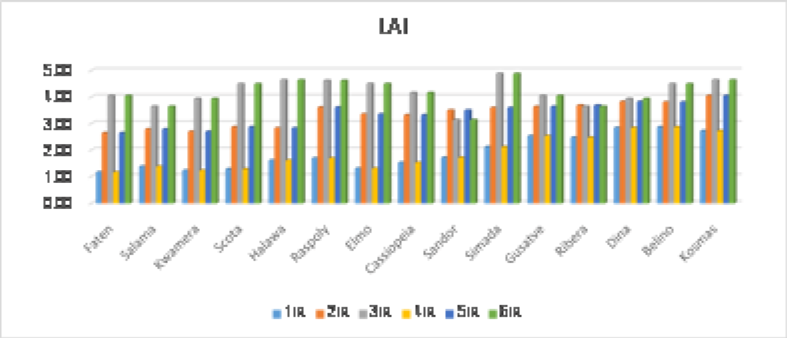

Figure 5: Leaf area index (LAI) % of sugar beet varieties as affected by different drought levels during 2021/2022 and 2022/2023 seasons. LSD = 0.326, 0.405 and 0.718for drought levels, varieties and interaction, respectively in the first season and LSD= 0.264, 0.387 and 0.675for drought levels, varieties and interaction, respectively in the second season.
**IR1 = 60%IWR, IR2 =80%IWR and IR3= 100%IWR in the first season, IR4 = 60%IWR, IR5 =80%IWR and IR6= 100%IWR in the second season.

shown that proline concentration was higher and significantly increased by decreasing IWR from 100% to 60% of the IWR in both seasons.

Proline

Results in (Figures 7 and 8) display proline varied significantly among varieties under drought stress in both seasons 2021/2022 and 2022/2023. The results shown that proline concentration was higher and significantly increased by decreasing IWR from 100% to 60% of the IWR in both seasons. According to Delauney and Verma (1993), proline seems to be the most extensively

dispersed metabolite that accumulates during stressful conditions. Well-established research (Hanson et al., 1977 and Hasegawa et al., 1994) shows that proline concentration rises in response to water deficit, and a substantial amount of evidence suggests a positive correlation between proline accumulation and improved resistance to drought stress and (Van Rensburg and Krüger, 1994). As well as, Ain-Lhout et al. (2001), proline

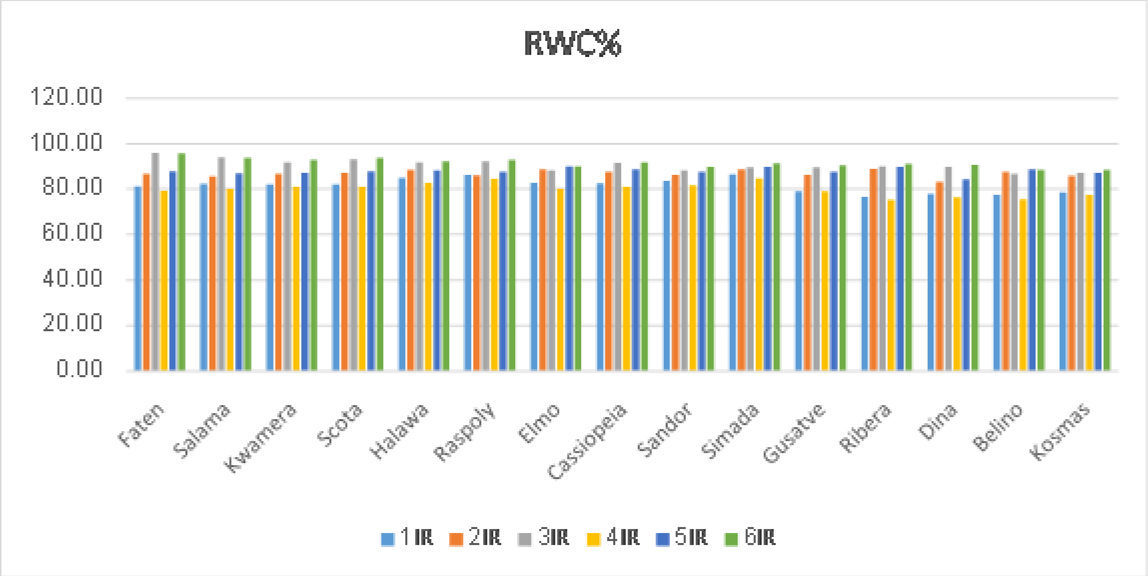

Figure 6: Leaf relative water content % (RWC%) of sugar beet varieties as affected by different drought levels during 2021/2022 and 2022/2023 seasons. LSD = 3.416, 2.734 and 5.238 for drought levels, varieties and interaction, respectively in the first season and LSD= 2.612, 2.403 and 4.457 for drought levels, varieties and interaction, respectively in the second season. **IR1 = 60%IWR, IR2 =80%IWR and IR3= 100%IWR in the first season , IR4 = 60%IWR, IR5 =80%IWR and IR6= 100%IWR in the second season.

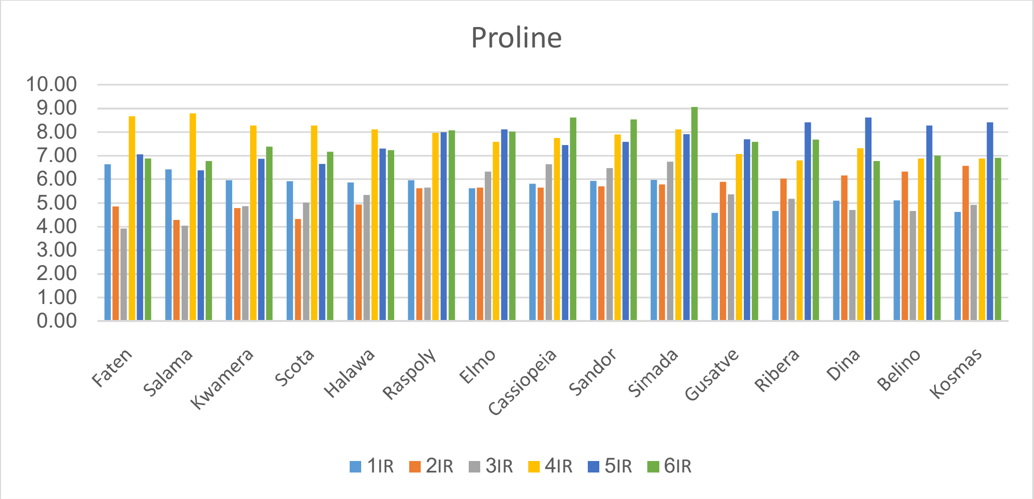

Figure 7: Proline % of sugar beet varieties as affected by different drought levels during 2021/2022 and 2022/2023 seasons. LSD = 1.157, 0.509 and 1.267 for drought levels, varieties and interaction, respectively in the first season and LSD= 1.021, 0.625 and 1.309 for drought levels, varieties and interaction, respectively in the second season. **IR1 = 60%IWR, IR2 =80%IWR and IR3= 100%IWR in the first season, IR4 = 60%IWR, IR5 =80%IWR and IR6= 100%IWR in the second season.

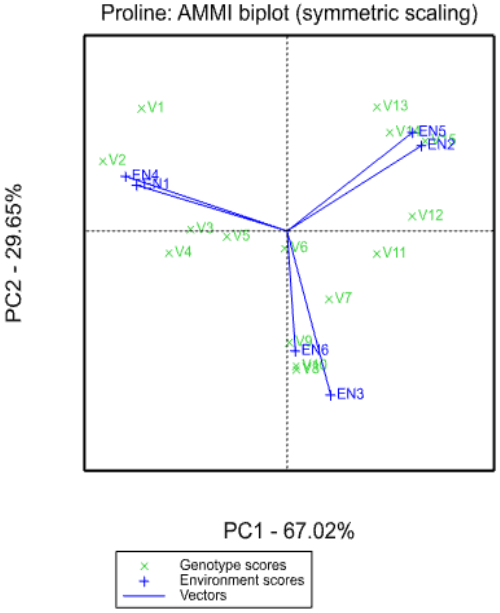

Figure 8. AMMI biplot presenting proline for 15 sugar beet varieties.

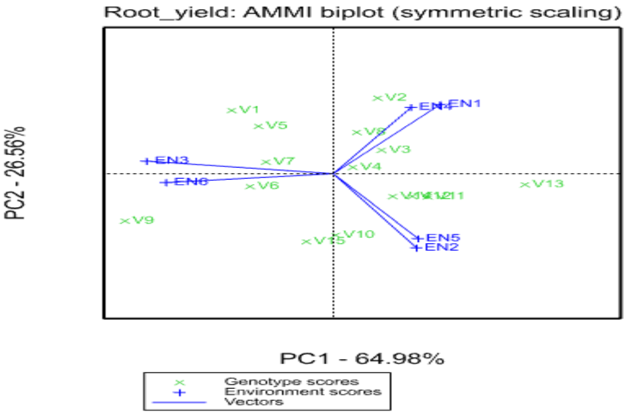

Figure 9. AMMI biplot presenting root yield for 15 sugar beet varieties.

accumulation appears to be a helpful indicator of drought stress in plants. Faten and Kosmas and Simada varieties recorded the highest values of proline under 60%, 80% and 100% of IWR in the first season, respectively. While, in the first season, Salama, Dina and Simada varieties recorded the highest values of proline under 60%, 80% and 100% of IWR, respectively. The first two interaction principal components (IPCA1 and IPCA2) for proline

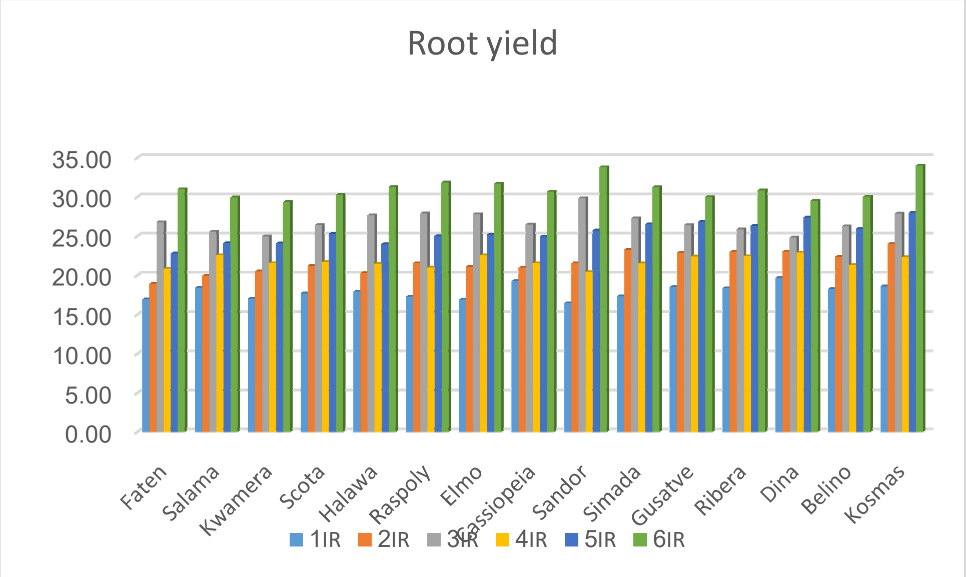

Figure 10: Root yield% of sugar beet varieties as affected by different drought levels during 2021/2022 and 2022/2023 seasons. LSD = 1.6, 1.523 and 2.807 for drought levels, varieties and interaction, respectively in the first season and LSD= 1.708, 1.407 and 2.676 for drought levels, varieties and interaction, respectively in the second season.
**R1 = 60%IWR, IR2 =80%IWR and IR3= 100%IWR in the first season, IR4 = 60%IWR, IR5 =80%IWR and IR6= 100%IWR in the second season.

accounted jointly for 96.67% of the variation caused by interaction (Figure 8). The varieties V13 (Dina), V14 (Belino) and V15 (Kosmas) interacted positively with the EN2 and EN5 treatments. The varieties V8 (Cassiopeia), V9 (Sandor) and V10 (Simada) interacted positively with the EN3 and EN6 environments. Varieties V1 (Faten) and V2 (Salama) interacted positively with the EN1 and EN4 environment.

AMMI Biplot

The first two interaction principal components (IPCA1 and IPCA2) for proline accounted jointly for 96.67% of the variation caused by interaction (Figure 8). The varieties V13, V14 and V15 interacted positively with the EN2 and EN5 treatments. The varieties V8, V9 and V10 interacted positively with the EN3 and EN6 environments. Varieties V1 and V2 interacted positively with the EN1 and EN4 environment. The stability of studied varieties can be evaluated as stated by biplot for root yield (Figure 9). The varieties V2 V3 and V6 interacted positively with the EN1 and EN2 treatments; correspondingly, the varieties V11 and V13 interacted positively with the EN2 and EN5 treatments based on sugar yield (fig 11 &12). The stability of studied varieties can be evaluated as stated by biplot for root yield (Figures 9 and 10). The varieties (Salama), (Kwamera) and (Raspoly) interacted positively with the EN1 and EN2 treatments, correspondingly, the varieties (Gusatve) and (Dina) interacted positively with the EN2 and EN5 treatments based on sugar yield in Fig 11 &12 . The main cause of the high sugar yield is high sucrose and extractable sugar.

Principal component analysis (PCA)

Utilizing PCA of standardized data, it was possible to illustrate the genetic variety across sugar beet root cultivars by comparing and contrasting cultivar features. Because various characters utilize different units, data standardization is required to eliminate the units. Values that are symmetrically distributed between the variety and character scores were obtained by scaling the principal components of PC1 and PC2 (Abo Elenen et al., 2019 and Mehareb et al., 2021 & 2023 and El-manhaly et al 2023). When evaluating the variety across sugar beet varieties using 15 traits, the first two components (PCA1 and PCA2) accounted for up to 76.6% (58.2% and 18.4%, respectively) of the overall variation among traits (Figure 11). When interpreting the rotation (farthest from zero), the first principal component (PCA1) is more important. For every stated phenotypic variation, the first principal component (PC) accounted for 58.2% of the total. Numerous indicators are available for analyzing

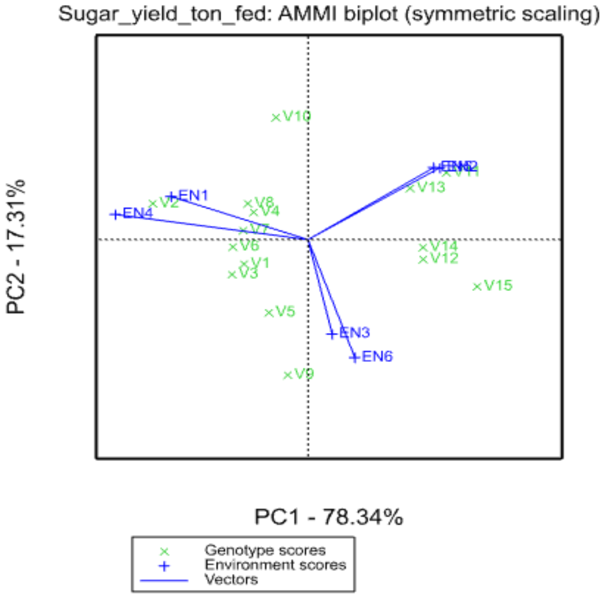

Figure 11. AMMI biplot presenting sugar yield for 15 sugar beet varieties.

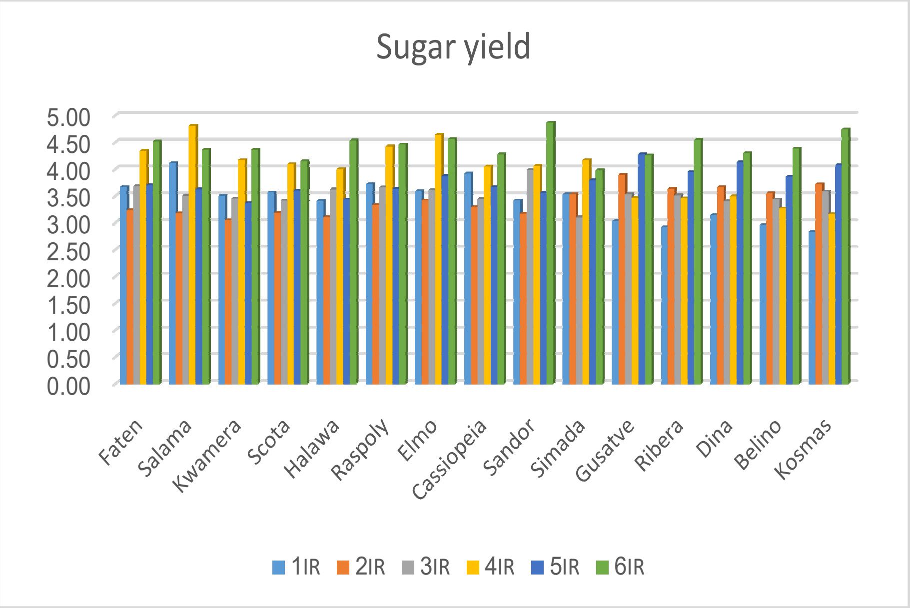

Figure 12: Sugar yield% of sugar beet varieties as affected by different drought levels during 2021/2022 and 2022/2023 seasons. LSD = 0.431, 0.356 and 0.677 for drought levels, varieties and interaction, respectively in the first season and LSD= 0.593 , 0.371 and 0.77 for drought levels, varieties and interaction, respectively in the second season.
**IR1 = 60%IWR, IR2 =80%IWR and IR3= 100%IWR in the first season, IR4 = 60%IWR, IR5 =80%IWR and IR6= 100%IWR in the second season.

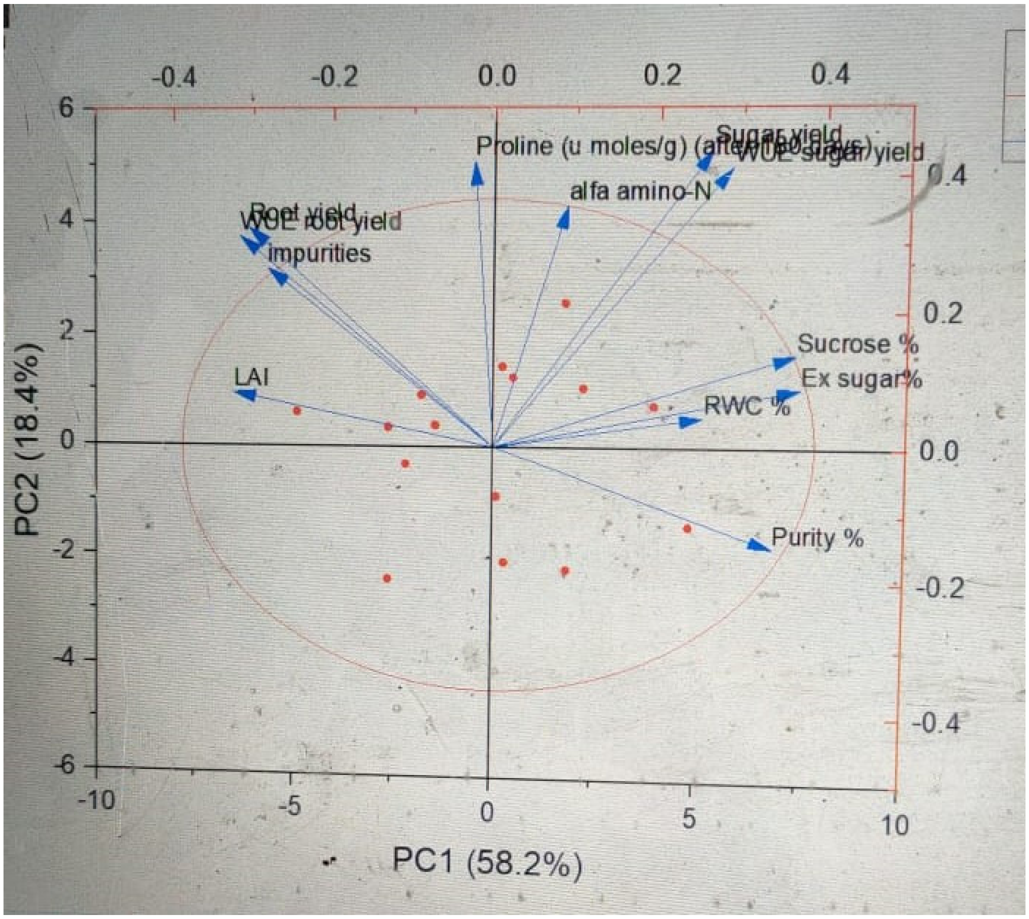

Figure 13: Biplot based on principal component analysis for characters in sugar beet varieties.

sugar beetroot genotype features, and quality variations between genotypes have been connected to numerous interrelated reasons (Xiao et al., 2017 and Mehareb et al., 2021). In general, variable indicators selected using the PCA technique based on several quality parameters may facilitate scientific screening of high-quality varieties and avoid resource waste in addition to expediting the evaluation process. As a result, the PCA technique has been applied to numerous crops (Abo Elenen et al., 2019 and Mehareb et al., 2021).The relationship between characteristics and varieties is examined using principle components analysis (Mehareb et 2023). A substantial positive correlation was established between root length and root weight when PCA, as shown in Figure 13, was applied to 12 sugar beet features. These results are consistent with those of El-manhaly et al (2023), who also found a positive association between root weight and root length. However, it also discovered a strong positive correlation between root length and root diameter, as well as between root diameter and top yield. It also discovered a strong positive correlation between proline and sugar yield, as well as a strong positive correlation between sucrose and purity. These findings are consistent with those of Gaballah and Mehareb 2020, Mehareb, El-Mansoub (2020), and Fahmy et al. (2021) who found a strong positive correlation between sucrose and purity. Figure 13 display highly significant and positive correlation between root yield, (Water use efficiency) WUE root yield and impurities, followed by root yield and (Leaf area index) LAI then root yield and proline while root yield negative correlation with purity% . In contrast, high positive correlation between sugar yield and proline, followed by proline and sucrose %.

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