The morphological and physiological responses of sugar beet to drought

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Introduction

Drought affect the most physiological processes, which influenced the plant productivity. Estimates of potential sugar beet yield losses in Europe, due to insufficient water resources, vary between 5 to 30% (Pingeon et.al., 2001). One solution is to breed beet varieties that are tolerant to water stress, based upon morphological, physiological, biochemical and molecular criteria. Appropriate criteria may be identified by detailed study of the water stress on this crop and its drought tolerance (Chołuj et al. 2014).

The aim of this study was to evaluate the influence of drought on the morpho-physiological traits in sugar beet plants.

Material and Methods

The experiment was conducted on 12 sugar beet breeding genotypes (*Beta vulgaris* L. subsp. *vulgaris*). All seeds were kindly provided by Kutnowska Sugar Beet Breeding Company (KHBC Ltd., Poland).

Plants were grown on Wagner pots in greenhouse of Warsaw University of Life Science. At the beginning of plant vegetation both control and drought-treated plants were irrigated to 60% of water- holding capacity (WC) on a weight basis every second day. Water supply was varied for drought-treated plants at 40 DAE (3-4 leaves stage) by reduction of watering to 30% WC. The following morpho-physiological traits were estimated: wilting of leaves (Wilt), specific leaf weight (SLW), relative water content (RWC), succulence index (Suc.I), leaves area, dry matter of particular plant's organs, the osmotic potential (ψs) and relative chlorophyll and flavonoids content of mature leaves, efficiency of the photosynthetic apparatus evaluated by chlorophyll a fluorescence parameters. Genetic distance was scoring using POP-GENE program based on calculated RAPD fragment bands.

Table 1. Effect of 47 days water stress on morpho-physiological traits of sugar beet plants (average of all genotypes and 2 assessment dates).

Traits	Control	Drought	Percentage of control [%]
Wilting score	1.52	3.24	213.1
RWC [%]	87.1	82.6	94.8
SLW [mg cm^{-2}]	4.79	5.34	111.5
Succulent index [mg H_2O cm^{-2}]	32.8	37.8	115.2
DM of blades [g]	4.96	3.25	65.5
DM of petioles [g]	3.55	2.12	59.7
DM of roots [g]	4.78	3.17	66.3
DM of whole plant [g]	13.28	8.54	64.3
Area of blades [dm^2]	1.01	0.61	60.4
Osmotic potential of leaves [Mpa]	-1.42	-2.38	59.7
NBI	37.58	30.66	81.6
Relative chlorophyll content	33.88	31.08	91.7
Relative flavonoids content	0.95	1.04	109.4
Effective quantum efficiency of PSII (Ø PSII)	0.723	0.590	81.6
Area under fluorescencje curve	98322	71346	72.5
Minimal fluorescence (Fo)	682	726	106.4
Maximal fluorescence (Fm)	4001	3813	95.3
Maximal quantum yield of PSII (Fv/Fm)	0.829	0.806	97.2
Efficiency of water splitting system(Fv/Fo)	4.92	4.41	89.6

Table 2. Drought tolerance index (DTI) calculated for morpho-physiological traits on a basis of average for all genotypes and 2 assessment dates.

Genotype	Wilt. scor	Suc. Index	Dray Matter				Leaves area	Ψ_s	NBI	Flavo-noids	Φ PSII	Area under fluoresce-nce curve
			Blades	Petioles	Roots	Plant						
1	0.92	1.05	1.20	1.45	0.89	1.13	1.11	0.95	0.92	1.15	0.96	0.99
2	1.05	1.15	0.71	0.73	0.69	0.71	0.74	0.87	0.83	0.98	0.85	0.84
3	0.84	0.89	1.26	1.51	1.18	1.28	1.42	1.08	1.09	0.97	1.16	1.42
4	0.91	0.97	0.78	0.81	1.04	0.88	0.78	1.02	1.05	1.00	0.99	1.25
5	1.00	0.97	1.27	0.99	1.11	1.15	1.36	1.04	0.95	1.03	1.07	0.87
6	1.10	0.97	0.97	1.00	1.17	1.07	1.03	1.06	1.11	0.92	1.12	0.94
7	1.03	1.00	1.13	0.73	0.99	0.96	1.11	1.00	1.17	0.96	1.04	0.88
8	1.11	1.01	1.19	1.02	1.17	1.14	1.29	1.06	1.03	0.91	0.94	1.15
9	1.17	1.13	0.57	0.83	0.71	0.69	0.44	0.89	0.80	1.14	0.89	0.85
10	0.85	0.97	1.25	1.58	1.24	1.33	1.20	1.09	1.19	1.03	1.13	1.23
11	1.01	0.95	1.26	1.22	0.92	1.12	1.22	0.96	0.90	1.08	0.90	1.18
12	1.08	0.97	0.72	1.19	0.95	0.91	0.69	0.98	1.04	0.86	0.98	0.69
Max-Min	0.33	0.26	0.70	1.12	0.55	0.64	0.98	0.22	0.36	0.29	0.31	0.73

Conclusions

Principal component analysis (Fig.2-drought) suggested that traits that are strongly correlated with storage root growth, either positively (e.g. maximum and effective quantum yield of PSII, relative chlorophyll content, leaves area, and ψs), or negatively (Wilt. and Suc.I), could be used as potential selection criteria in breeding programmes to improve drought tolerance in sugar beet.

Fig.1. Relationships between the examined traits evaluated by principal component analysis (PCA) based on the means for all genotypes (control) and 2 assessment dates.

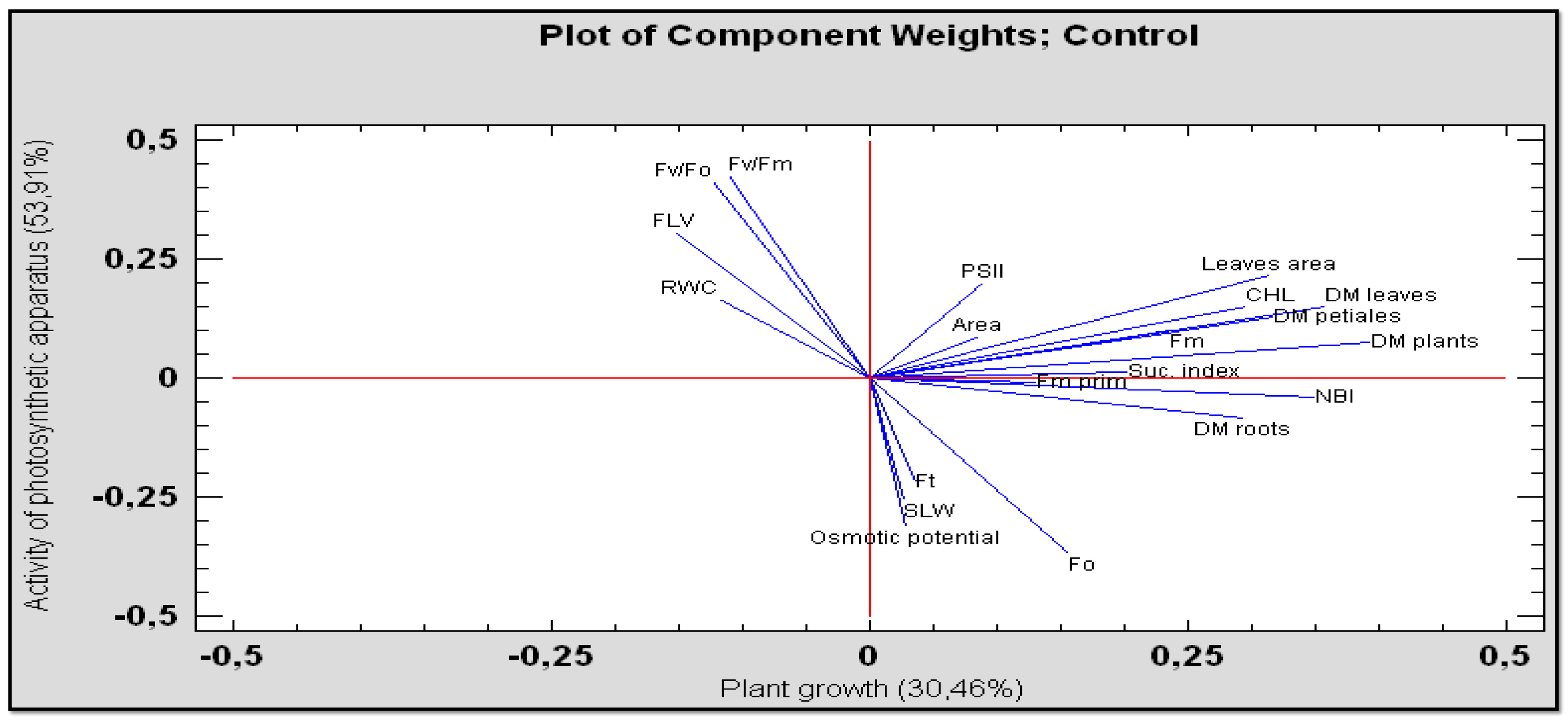


Fig.2. Relationships between the examined traits evaluated by principal component analysis (PCA) based on the means for all genotypes (drought) and 2 assessment dates.

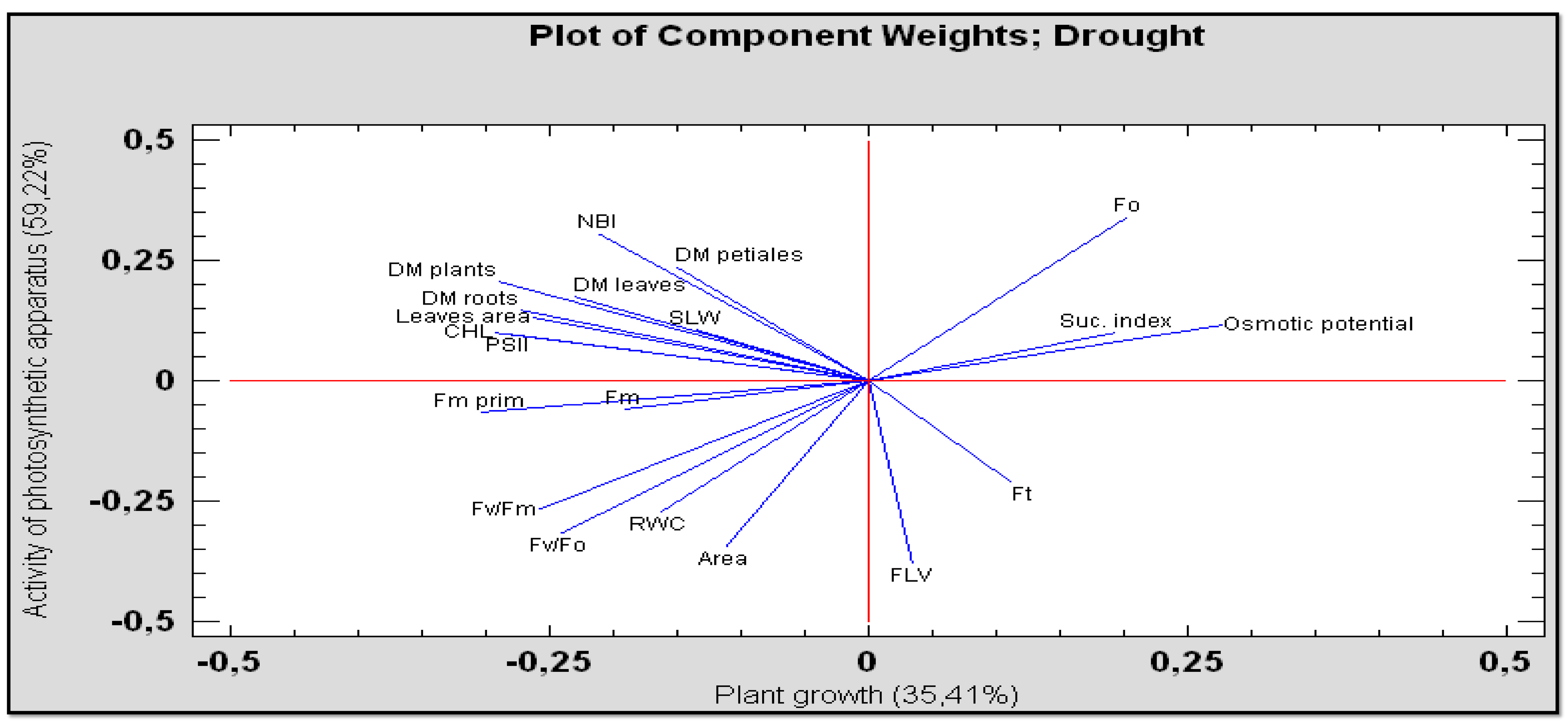
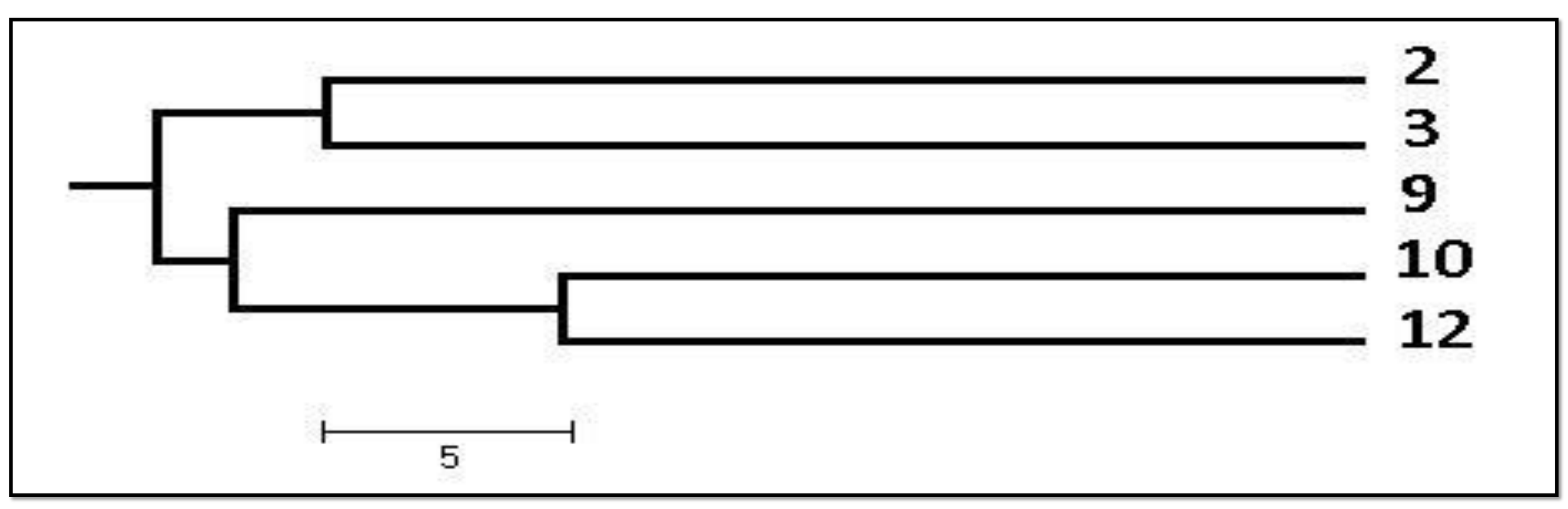


Fig.3. Dendrogram of genetic distance between genotypes most varied in their drought response.



Results

Reduction of water supply for 47 days significantly increased the wilting of leaves (Wilt.) and the succulence index (Suc.I), while the specific leaf weight (SLW), relative water content (RWC) of mature leaves and leaf senescence measured as relative content of chlorophyll were only slightly affected. Simultaneously, the osmotic potential (ψs), leaves area, dry matter of particular plant's organs and the efficiency of the photosynthetic apparatus estimated by chlorophyll a fluorescence parameters declined under water deficit conditions. As a consequence of water deficit growth of plant were lowered by approximately 40%, compared with optimally irrigated plants (Tab.1). The examined genotypes demonstrated a clear diversity in their morpho-physiological responses to drought (Tab.2). The genetic distance (ranged from 0.31 to 0.51) between genotypes most varied in their drought response shows relatively high level of their biodiversity (Fig.2).

References

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