PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol 9(4): 1045–1048
https://doi.org/10.14719/pst.1757

HORIZON
e-Publishing Group

RESEARCH ARTICLE

The influence of soil types and fertilizers on growth parameters of three goatgrass species (*Aegilops*) from the coastal plains of Israel: A. *sharonensis* Eig, *A. longissima* Schwienf. et Muschl. and *A. speltoides* Tausch

Moshe Agami[1], Yehoshua Anikster [1] & Amir Neori [2,3*]

[1] School of Plant Sciences and Food Security, The George S. Wise Faculty of Life Sciences, Tel Aviv University, 6997801 Tel Aviv, Israel
[2] Morris Kahn Marine Research Station, The Leon H. Charney School of Marine Sciences, University of Haifa 3498838, Israel
[3] The Interuniversity Institute for Marine Sciences in Eilat 8810302, Israel

*Email: aneori@univ.haifa.ac.il

OPEN ACCESS

ARTICLE HISTORY
Received: 15 March 2022
Accepted: 09 August 2022
Available online
Version 1.0 : 07 October 2022

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS etc.
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

CITE THIS ARTICLE

Agami M, Yehoshua Anikster Y, Neori A. The influence of soil types and fertilizers on growth parameters of three goatgrass species (*Aegilops*) from the coastal plains of Israel: *A. sharonensis* Eig, *A. longissima* Schwienf. et Muschl. and *A. speltoides* Tausch. Plant Science Today. 2022; 9(4): 1045–1048. https://doi.org/10.14719/pst.1757

Abstract

Three species of goatgrass (*Aegilops* L.), the wild relative of wheat, grow naturally in the coastal plains of Israel. The distribution and ecological parameters of *Aegilops sharonensis* were determined by a field survey, while similar information on the other species was obtained from the BioGIS database. The distribution of plants was soil-specific. Sharon goatgrass (*A. sharonensis* Eig) is endemic to Israel and southern Lebanon's coastal plains, which have been stabilized with dunes and sandy soils. In contrast, slender goatgrass (*A. longissima* Schwienf. et Muschl.) grows mainly on sandy loam and the truncate goatgrass (*A. speltoides* Tausch) grows primarily on heavy alluvial soils. The present 4-month study evaluated the affinity between these 3 *Aegilops* species, the 3 different types of soils and fertilizer application, in buckets. Interestingly, a significant increase in the number and weight of the spikes were observed in fertilized buckets. We could also find that these 3 species preferred heavy alluvial soil over the sands, regardless of the fertilizer treatment. The data suggested that the population of *A. sharonensis* was limited to the sandy dunes by urbanization along the coastal plane and aggressive competition with the other species. Their more extended root system may adapt *A. sharonensis* to the deep and salty groundwater that characterizes dunes. It is suggested to keep representatives of the Israeli *Aegilops* populations in a nature reserve for protection from extinction.

Keywords

Bucket-study, ecosystem, groundwater, sand, dunes, urbanization, goatgrass, spikes, distribution

Introduction

The coastal plain of Israel features mosaics of soils, from dunes and stabilized sands to sandy loam, heavy alluvial soils to calcareous soils embedded within sands. The plain borders Lebanon in the north, the Gaza strip in the south, the Mediterranean Sea in the west and about 15 km eastwards (1). Three annual goatgrass species (*Aegilops* L.), Sitopsis section, Poaceae (2, 3), grow naturally on the coastal plain of Israel, on different types of soils (2). Sharon goatgrass (*A. sharonensis* Eig) is an endemic grass that grows exclusively on stabilized dunes and sandy soils. In contrast, slender goatgrass (*A. longissima* Schwienf. et Muschl.) grows mainly on sandy loam soil, and truncate goatgrass (*A. speltoides* Tausch) grows primarily on heavy alluvial soils (3). These diploid (2n=14) species share a similar 'S' genome, with some modifications that differentiate them. These genomes and especially that of *A. speltoides* are closely related to the 'B' genome of the polyploid, wild and domesticated wheat (4). Extant populations of *A. sharonensis* that survived in their natural habitats were collected for this study in 2003-2004. Physical and ecological data of the populations were recorded and the data were published (4). Data on the 2 other species were obtained from published work (10).

The prevalence of *A. sharonensis* on dunes and sand near the sea suggests that it may be a donor of genes to wheat for tolerance to soil salinity, mineral deficiencies, heat and additional traits (5-8). In addition, heat tolerance genes can be beneficial to wheat during global warming (5). Therefore, the genus is a valuable source of genes for wheat (*Triticum aestivum* L.) improvement (6-8).

The available literature shows that these 3 species were reported in many locations along the coastal planes (9). However, most of these reports are dated and many involved ecosystems have been lost in the 20th and 21st centuries due to urbanization and farming advances (7). In addition, due to the dynamic changes in its ecosystem, it is difficult to assess the threat to the genetic diversity of these goatgrass species without knowing their distribution (10). Therefore, the present study experimentally determines the preferred natural soil and nutrient requirements of each of the 3 goatgrasses and in so doing closes an information gap created by the lack of ecological-physiological studies on the Israeli *Aegilops* species since (1).

Materials and Methods

A greenhouse bucket study using 3 different soils (sand, sandy loam, and heavy alluvial) and the 3 *Aegilops* species (*A. sharonensis* (TH), *A. longissima* (TL) and *A. speltoides* (TS)) with or without chemical enrichment was used to study the affinity between each species and the soils as well as the effect of chemical enrichment (a simulation of fertilizer application). The experiment was run during winter (starting in February). The temperature ranged between 10-15 ^{0}C.

Fifty seeds of each species were soaked in water to promote germination as in (12). Then, 10 liter buckets were washed, saturated with water and filled with the respective soils. Two plantlets were planted in each bucket. Each chemical supplementation was done in triplicates and maintained in a greenhouse using a randomized block design.

Of the 6 buckets with each soil, 3 received a solution with additional fertilizer ("Shefer 6-6-6+3", with 6% N – as ammonium and nitrate, 6% K_2O, 6% P_2O_5, 0.03% Fe and microelements, 0.5 cc L^{-1}) (Haifa Group Chemicals, cat no. 151519, https://www.iclhaifa.com/fertilizers/images/products-pdf/SHEFER.pdf).

Approximately 170 cc solution or clean water was added twice a week to each bucket for 4 months. Each of the 3 species blocks consisted of 2 sub-blocks of 9 buckets watered with pure or fertilized media.

Spikes count and spike weight were collected to assess growth (13). Briefly, at plant maturity, each spike was clipped at its base and the spikes of each plant were counted, dried in an incubator (at 40 °C) until they attained a constant weight and weighed.

Artwork and statistics

Artwork and statistics were made with GraphPad Prism 9.3. The data were first analyzed with a two-way ANOVA. Then, differences between group means were evaluated for statistical significance using one-way ANOVA (ns, not significant; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; ****$p < 0.0001$). Error bars represent the standard deviation of the mean.

Results

The data on the distribution of *A. sharonensis* in Israel have been published elsewhere (4). We have identified 42 separate Sharon goatgrass *A. sharonensis* (TH) populations along the coastal shores between Naharia in the north to Gaza in the south. Populations were distributed in variably -sized islands (from ten m^2 to a couple of km^2) of abundant plant islands separated by variable distances (4.(

The number (Table 1 and Fig. 1A, 2A) and the weight per plant (Fig. 1B, 2B) of the spikes were measured. It was found that all 3 goatgrass species preferred ($p < 0.0001$) the heavy alluvial soil over the 2 other sand types, regardless of the chemical supplement fertilizer. It significantly increased the number of spikes per plant ($p < 0.0009$) and total spike weight per plant ($p < 0.0001$) in the entire study.

Table 1. The number of spikes per plant (± standard error of the mean) in three species of *Aegilops: A. sharonensis* (TH), *A. longissima* (TL) and *A. speltoides* (TS) grown with and without fertilizer application in three soil types.

Soil type	Species	TH	TL	TS	mean
	Non-fertilized				
	Heavy	12.7 ±5.24	18.3 ±4.81	23.3 ±2.40	18.11 ±3.06
	Loam	5.7 ±1.20	4.3 ±0.67	13.0 ±2.89	7.67 ±2.70
	Sand	7.3 ±1.20	9.0 ±1.53	13.7 ±3.48	10.00 ±1.91
	mean	8.55 ±2.12	10.5 ±4.11	16.7 ±3.32	11.93 ±2.45
	Fertilized				
	Heavy	26.3 ±3.76	24.0 ±5.13	26.0 ±5.03	25.44 ±0.722
	Loam	17.7 ±2.91	19.0 ±4.58	23.3 ±1.45	19.67 ±1.69
	Sand	12 ±2.08	11.0 ±1.73	13.7 ±6.94	13.22 ±1.18
	mean	19.22±3.72	18.00±3.79	21.1 ±3.31	19.44 ±0.996
	Averages				
	Heavy	19.5 ±6.80	21.2 ±2.85	24.7 ±1.35	21.8 ±1.94
	Loam	11.7 ±6.00	11.7 ±7.35	18.2 ±5.15	13.7 ±1.86
	Sand	10.5 ±3.20	10.0 ±1.00	14.3±0.650	11.6 ±1.31
	mean	13.89±3.06	14.28±3.01	18.89±2.35	15.69 ±2.07

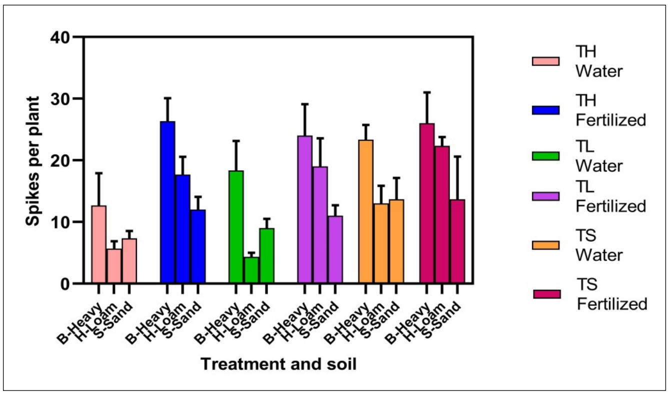

Fig. 1A. The effect of two levels of fertilizer application (Water-none and Fertilizer-a complete fertilizer solution) and three soil types (B-heavy loam, H-loam, and S-sand) on the number of spikes per plant for each of the three goatgrass species, *Aegilops sharonensis* (TH), *A. longissima* (TL) and *A. speltoides* (TS).

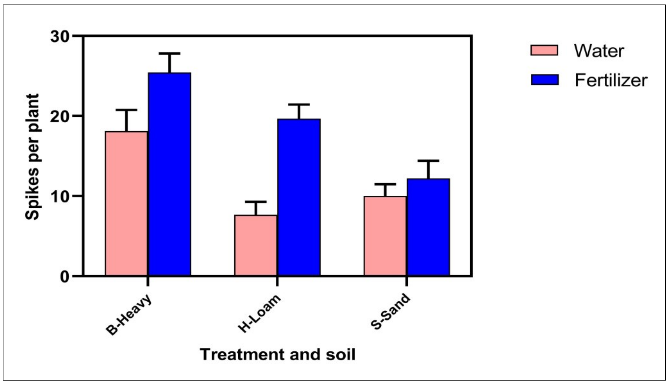

Fig. 1B. Effect of fertilizer application on the number of spikes per plant averaged for the 3 goatgrass species in each soil.

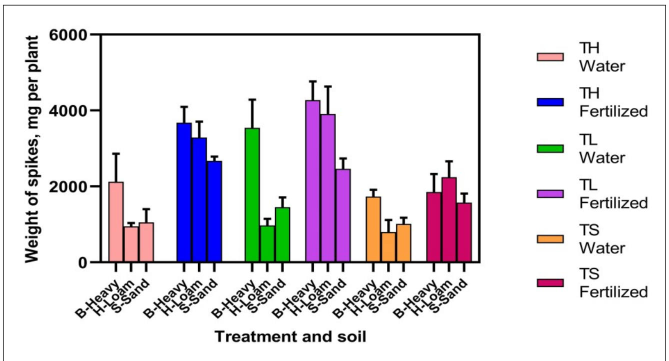

Fig. 2A. The effect of two levels of fertilizer application (Water-none and Fertilizer-a complete fertilizer solution) and 3 soil types (B-heavy loam, H-loam and S-sand) on the total weight (mg) of spikes per plant for each of the three goatgrass species, *Aegilops sharonensis* (TH), *A. longissima* (TL) and *A. speltoides* (TS).

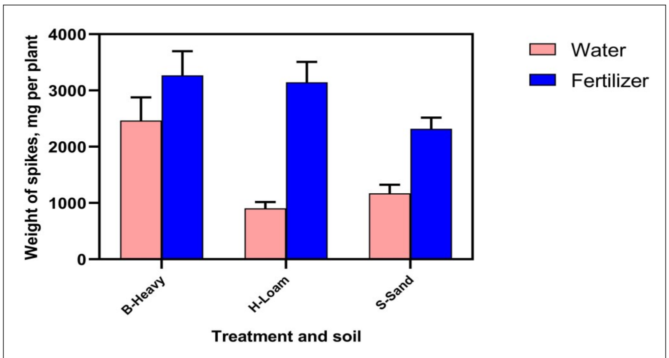

Fig. 2B. The effect of fertilizer application on the weight of spikes per plant averaged for the three goatgrass species in each soil.

It was found that chemical supplementation resulted in an increased number of spikes in all 3 species regardless of the type of soil (Fig. 2A). However, the effect of chemical supplementation on the increased number of spikes was obtained only in the heavy alluvial ($p < 0.015$) and in the sandy loam ($p < 0.001$) soils. Furthermore, this impact was even more substantial in the loam and sand soils when measuring the total spike weight per plant (Fig. 2B). The significance values for the impact of chemical supplements on the total spike weight per plant were 0.2, 0.001 and 0.001 in the heavy soil, loam and sand respectively.

A. sharonensis and *A. longissima* without chemical supplementation shows a reduction (57%) in the number of spikes per plant compared to *A. speltoides*. However, with the chemical supplement, the values were similar in the 3 species. Fertilizer supplements increased the number of spikes per plant and spike weight in *A. sharonensis* more than the other 2 species (Fig. 1, 2).

The chemical treatment doubled the number of spikes per plant in *A. sharonensis,* and showed ($p = 0.0017$) 38% of the variance, while soil explained ($p = 0.018$) 27% of the variance.

In *A. longissima,* the fertilizer supplementation increased the number of spikes per plant by 70% and showed ($p = 0.025$) 19.6 % of the variance, whereas soil expressed ($p = 0.018$) 34% of the variance.

In *Ae. speltoides,* the fertilizer supplement increased the number of spikes per plant merely by 24% ($p=0.26$) with 6.4% of the variance and soil expressed 33% of the variance ($p = 0.057$).

Separating the fertilizer application and the soil effects by 2-w ANOVA species-by-species, the impact of soil and fertilizer application on the number of spikes per plant and total spike weight per plant were significant only in *A. sharonensis* and *A. longissima* (Table 2). In *A. speltoides,* only the impact of fertilizer application on the total spike weight per plant was significant (Table 2).

Table 2. Statistical analyses of variance (p values) in the growth results. *Aegilops sharonensis* (TH), *A. longissima* (TL) and *A. speltoides* (TS). $ a marginal significance.

Impact of	Measurement	Species		
		TH	TL	TS
Soil	Spikes per plant	0.018*	0.018*	0.058$
	Total spike weight per plant	0.055$	0.0055**	0.3817
Fertilizer application	Spikes per plant	0.0017**	0.025*	0.26
	Total spike weight per plant	<0.0001***	0.0024**	0.0264*

Discussion

Our experimental study shows Sharon goatgrass grows better on heavier soils, with or without fertilizer application, regardless of its sandy habitat. However, its deeper rooting system, prevalent rhizosphere microorganisms, mycorrhizal fungi and perhaps salt tolerance (8, 14) give this species an advantage over the 2 others in sands with deeper groundwater.

All three species of goatgrass grown in buckets preferred the heavy textured alluvial soil. Therefore, the field observations are intriguing because only *Aegilops sharonensis* grows on the sandy coastal soils, while the 2 other species avoid the sandy sites and occupy the richer soils.

It was suggested that the extant populations of *A. sharonensis* and perhaps the other 2 species have been squeezed by urbanization, farming and other aggressive plant species to unfavorable and unpredictable conditions that characterize the sandy patches in the Mediterranean Coastal Plain (7). *A. speltoides* plants are relatively sturdier than the 2 other species, judging by their smaller response to the treatments. The 2 goatgrass, namely, *A. longissima* and *A. speltoides* are more aggressive but suffer from heat stress (11). They may also be less tolerant to salt, which characterizes coastal sand. These two successful species pushed *A. sharonensis* to the margins of the preferable rich soils, so that *A. sharonensis* could develop only in the sandy regions, which are the lowest quality sites in the coastal plains. As a result, *A. sharonensis* was excluded from its preferred rich soils, leaving it to thrive only in the warmer, desert-like, saltier and dryer coastal dunes and sand, where the underground water lies below the root zone of many annual plants despite the sufficient rainfall (1). Therefore, we suggest that the continuous stress conditions on the sandy soils gradually stimulated and promoted the development of a new species, namely, the development of the endemic *A. sharonensis*, which was isolated from the 2 original *Aegilops* populations by the warm and mineral-poor sandy habitat.

Conclusion

Aegilops sharonensis is an essential species for agriculture as its DNA composes the secondary gene pool that is useful for wheat improvement (9). The loss of its natural ecosystems in the coastal planes, combined with the economic importance of this species's genes for future wheat improvement, make it imperative to keep representatives of *A. sharonensis* populations in nature reserves and botanical gardens before the plant is extinct. Our finding of the unexpected preference of *A. sharonensis* for growing on heavy alluvial soils makes it preferable to safe keep a diversity of *A. sharonensis* seeds from isolated populations on such soils for future use.

Acknowledgements

The authors thank E Millet, S S Reuveny and R Aloni for their generous assistance in preparing and revising the manuscript.

Authors contributions

YA participated in the study's design, carried out the bucket experiment, organized the data, and participated in the ecological survey and the statistical analysis. MA conceived the study and participated in its design and coordination, participated in the ecological survey, drafted the manuscript and participated in the preparation of the MS. AN participated in the literature survey, the statistical analysis and the artwork, and prepared the final MS. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None.

References

1. Waisel Y, Litav M, Agami M. Coastal Plants of Israel. Division of Ecology Ltd., Tel Aviv; (in Hebrew). 1975.
2. Kilian B, Mammen K, Millet E, Sharma R, Graner A, Salamini F *et al.* In: Wild crop relatives: Genomic and Breeding Resources. Berlin, Heidelberg: Springer. 2010; 1-76. https://doi.org/10.1007/978-3-642-14228-4_1
3. Sela H, Ezrati S, Olivera PD. Genetic diversity of three Israeli wild relatives of wheat from the Sitopsis section of *Aegilops*. Israel Journal of Plant Sciences. 2018;65(3-4):161-74. https://doi.org/10.1163/22238980-00001059
4. Millet E, Agami M, Ezrati S, Manisterski J, Anikster Y. Distribution of Sharon goatgrass *(Aegilops sharonensis* Eig) in Israel. Israel Journal of Plant Sciences. 2006;54: 243-48. https://doi.org/10.1163/22238980-00001059
5. Ostrowski MF, Prosperi JM, David J. Potential implications of climate change on *Aegilops* species distribution: sympatry of these crop wild relatives with the major European crop *Triticum aestivum* and conservation issues. PloS one. 2016; 11(4): e0153974. https://doi.org/10.1371/journal.pone.0153974
6. Kushnir U, Halloran GM. Evidence for *Aegilops sharonensis* Eig as the donor of the B genome of wheat. Genetics. 1981;99(3-4): 495-512. https://doi.org/10.1093/genetics/99.3-4.495
7. Olivera PD, Anikster Y, Steffenson BJ. Genetic diversity and population structure in *Aegilops sharonensis*. Crop Science. 2010; 50(2): 636 -48. doi: 10.2135/cropsci2009.04.0192. https://doi.org/10.1111/1462-2920.14530
8. Llorens E, Sharon O, Camañes G, García-Agustín P, Sharon A. Endophytes from wild cereals protect wheat plants from drought by alteration of physiological responses of the plants to water stress. Environmental Microbiology. 2019;21(9):3299-312. https://doi.org/10.1111/1462-2920.14530
9. Ankori H, Zohary D. Natural hybridization between *Aegilops sharonensis* and *Ae. longissima*: a morphological and cytological study. Cytologia. 1962;27(3):314-24 https://doi.org/10.1508/cytologia.27.314
10. BioGIS Database of Israeli flora and fauna website: http:/www.biogis.huji.ac.il/biogis/static/he/index.html
11. Pradhan GP, Prasad PVV, Fritz AK, Kirkham MB, Gill BS. High temperature tolerance in *Aegilops* species and its potential transfer to wheat. Crop Science. 2012; 52(1): 292-304. https://doi.org/10.2135/cropsci2011.04.0186
12. Fang F, Zhang C, Wei S, Huang H, Liu, W. Factors affecting Tausch's goatgrass (*Aegilops tauschii* Coss.) seed germination and seedling emergence. Journal of Agricultural Science. 2012;4(1):114-21 https://doi.org/10.5539/jas.v4n1p114
13. Young FL, Yenish JP, Walenta DL, Ball DA, Alldrege JR. Spring-germinating jointed goatgrass (*Aegilops cylindrica*) produces viable spikelets in spring-seeded wheat. Weed Science. 2003;51(3):379-85. https://doi.org/10.1614/0043-1745(2003)051[0379:SJGACP]2.0.CO;2
14. Batten KM, Scow KM, Davies KF, Harrison SP. Two invasive plants alter soil microbial community composition in serpentine grasslands. Biological Invasions. 2006;8(2):217-30. https://doi.org/10.1007/s10530-004-3856-8

§§§