Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 23, Issue 3, 2023
PRINT ISSN 2284-7995, E-ISSN 2285-3952

SORGHUM, AN ALTERNATIVE IN COMPLEMENTARITY WITH CORN, ADAPTED TO CLIMATE CHANGES. AMZACEA VILLAGE, CONSTANTA COUNTY, ROMANIA

Dumitru MANOLE[1, 2], Ana Maria GIUMBA[2], Laurentiu GANEA[2]

[1]Academy of the Romanian Scientists, 3, Ilfov Street, Bucharest, Romania, E-mail: dumitrumanole38@yahoo.ro
[2]Commercial Company Sport Agra Ltd., 4, Zorelelor Alley, Amzacea Village, Constanta County, Romania, Mobile Phone: 0722698668, E-mails: dumitrumanole38@yahoo.ro, anamaria.giumba@yahoo.com, ganealaurentiuluca@gmail.com

Corresponding author: dumitrumanole38@yahoo.ro

Abstract

The geographical area between the Danube and the Black Sea, Dobrogea, represents a region with the highest aridity indices. The average precipitation in the period 1961-2016 was 464 mm. Climate changes in recent years have accentuated this phenomenon and, due to this, low production levels of 1-2 tons/ha were achieved on large areas of corn. In the year 2022/2023, over 40,000 ha cultivated with corn in Constanta county were deeply affected by the lack of rainfalls, high temperatures and long and severe drought. In these particularly dry conditions, sorghum becomes an essential alternative. This study aimed to continue the experiments with sorghum hybrids which have been carried out during the last 15 years at SPORT AGRA Ltd from Amzacea Village, Constanta County, in order to adapt the technologies to climate changes. The novelty of this research is that the adapted technologies include, among other things, the following elements: changing the planting period by approximately 25-30 days compared to the recommendations of classical technologies (planting starting from the first decade of May in order to use the moisture in the soil layer at the depth of seed incorporation 4-5 cm.), the use of early hybrids in order to overcome the periods of heat that in this area start from mid-June, the use of technological means of crop protection that include pre- and post-emergent herbicides, seed treatment prior to planting. In these conditions of development of non-irrigated sorghum technology, we propose planting this crop earlier (25-30 days compared to classic technology). In this way, the sorghum will benefit from the water reserve accumulated during the fall of the previous year. The productions of the sorghum hybrids used in the observation research fields were over 10 to/ha in most of the tested hybrids.

Key words**:** *Sorghum, hybrids, climate changes, technologies, pathogens*

INTRODUCTION

Sorghum is considered one of the oldest cultivated plants, the cultivated form very probably coming from the "domestication" in Africa 5-7000 years ago of the wild species *Sorghum arundinaceum* (Desv.) Stapf. Later, probably between the years 1500-100 B.Ch., Sorghum arrived in India and China, then in the Near East and in the first centuries of our era in the Mediterranean basin. Specialized literature records the culture of sorghum in the 9th century in Zanzibar [8], East India, in Italy in the 13th century. The Americans brought it from Asia - Franklin found some seeds in a brush and cultivated them.

In Romania, the first experiments with Sorghum were carried out at the Valul lui Traian Research and Development Station in 1961. A number of 13 grain sorghum hybrids were tested compared to the HD402 double corn hybrid, the results being exposed in Table 1.

The data from Table 1 show that the sorghum hybrids registered a higher yield than the HD402 corn hybrid. This additional yield varied between + 687 kg/ha and +3,098 kg/ha.

Parallel to the experimentation of a large number of foreign hybrids, the first sorghum improvement research works were initiated at the "Research Institute for Cereals and Technical Plants" Fundulea [14], completed by the approval of the first Romanian sorghum hybrid F31 in 1965 and later the F21, F30 and F32 hybrids.

Table 1. Comparison between HD 402(Maize) hybrid and various sorghum hybrids regarding plant height, vegetation period and yield

Hybrid	Plant height (cm)	Vegetation period (days)	Average production kg/ha	Diff. ±
HD 402 (Corn)	220	132	5,054	0
NK 300	156	143	8,152	+3,098
NK 120	118	128	7,905	+2851
X 3000	109	125	7,646	+2,592
X 3021	129	135	7,611	+2,557
X 3057	170	130	7,476	+2,422
X3007	108	148	7,322	+2,268
NK 310	113	146	7,057	+2,003
NK 230	103	136	6,867	+1,854
NK 145	225	130	6,815	+1,761
NK 135	122	131	6,670	+1,616
NK 135 11	136	145	6,657	+1,603
X 3037	102	145	6,459	+1,405
NK 140	118	138	5,741	+687

Source: Valul lui Traian Research and Development Station for Agriculture, Constanta County [33].

The plant breeding works had several objectives: precocity, low content in tannin and hydrocyanic acid, improvement of tolerance to salinity and soil alkalinity.

The botanical characteristics of this plant and the chemical composition, the carbohydrate juice content led to the creation of the Carmen hybrid for sweetened sorghum and Donaris hybrid for brooms.

In 1943, Italian sorghum was produced in Romania for export.

In 1986, sorghum was cultivated on 90,000 ha carrying out a yield of 1,860 kg/ha (Romania's Statistical Yearbook 1990) [27].

In 2003, a number of 8,765 agricultural holdings cultivated 11,092 ha with sorghum in Romania [21].

In 2003, at the world level, there were 44 million hectares cultivated with sorghum, of which the largest areas in India 10 million hectares (22.72%).

Globally, sorghum has a share of 16% of the total cultivated area with cereals and 25% in the developed countries [4].

Among cereals crops at world level, Sorghum Sp. comes of the 5th position after maize, rice, wheat and barley [25].

In 2017, the world Sorghum production reached 63.9 million tonnes, and the average yield 1,427 kg/ha. The main producers of Sorghum were the USA, Nigeria, Sudan, Mexico, Ethiopia and India [26].

In 2020-2021, it was produced over 60 million tons sorghum. The main producing countries were Nigeria, USA, Sudan and Mexico.

In 2022, an area of 40 million ha was cultivated with this crop [7]. This reflects a decline in cultivated area and also yield decreased in the top producing countries. About 34% of the cultivated area is in India and Sudan, whose sorghum production accounted for 17% of the global output [12].

In the EU, in 2017, sorghum represented only 0.12 % of the world cultivated area with this plant and there were achieved 755 thousand tonnes of grains (1.18 % of the world output).

With 5,580 kg/ha average yield, the EU exceeds 3.81 times the world mean. The main EU producers of Sorghum are: Italy, France, Spain, Romania, Austria, Hungary, and Bulgaria [26].

In the EU in 2022, there were 183,000 ha cultivated with sorghum. From the total EU production, 41% is achieved in France, 34% in Italy, 8% in Hungary and 7% in Romania [32].

In 2023, the largest cultivated areas with sorghum in the EU are in France 51,000 ha and Italy 40,000 ha. The highest production is obtained in Italy, 260,000 tons and France 219,000 tons, while the top yield was registered in Italy 6,500 kg/ha, Greece 5,200 kg/ha and France 4,300 kg/ha [5].

The main aspects of interest for research on sorghum crop are: testing hybrids with high production potential [11], sorghum roots and yield response to soil water status [13, 19, 34]. sorghum root system development compared to maize [28, 30], influence of temperature on sorghum grains germination [24], sorghum tolerance to climate risk [12],

adaptation to heat stress of grains crops by sowing in other period to avoid heat and drought [35], sowing from 20 April till 15 May depends on climate [8], sorghum an alternative and a complementary crop for maize in Dobrogea region [15], adaption of sorghum technology to climate change risk [15, 16, 17, 18, 31].

In this context, the purpose of this research work is to develop experiments destined to test the planting period, tolerance to drought conditions and burn, diseases and pests specific to the area, production levels of various sorghum hybrids under the climate conditions where the Commercial Company Sport Agra Ltd. in running its activity, in Amzacea village, Constanta county, Romania. The results have to provide useful information to the farmer to make the right decision concerning the best hybrids which could produce the highest yield and deserve to be cultivated in the future.

MATERIALS AND METHODS

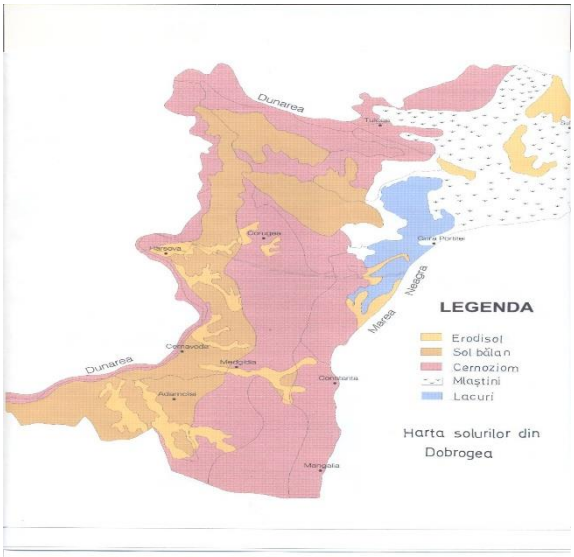
Starting with 2012, the first experiments with various sorghum hybrids in the fields of comparative crops were developed by the Commercial Company Sport Agra Ltd, Amzacea village, Constanta county, aiming at adapting various hybrids to climate changes by testing the planting period [3, 35], tolerance to drought conditions and burn, diseases and pests specific to the area, production levels.

The experimental plots were located on a soil belonging to the Southern Dobrogea plateau.

The soil is represented by cambic chernozem, with a deeper profile than that of other chernozems, a blackish brown soil with a thickness of 40-50 cm, medium texture [6] (Map 1).

The soil nutrient content was: --mobile P index – 72 --N index – 4 --humus – 3.11 --K index – 200 --neutral pH – 7.2.

The climate is deeply temperate continental, with an average annual temperature of 10.7-12.12°C, with a high temperature accompanied by heat between the beginning of June and the end of August.



Map. 1. Soil map in Dobrogea region, Romania
Source: Soil Science Office, Constanta [29].

Dobrogea region has a temperate continental climate. It frequently faced drought, an endemic phenomenon "During dry years, periods of drought can last 60-100 days, sometimes even longer", as affirmed [9].

Among the last 10 years, 5-6 were dry or excessively dry years. The calamity of agricultural crops cost the state budget over 500 billion lei until 2007 [23].

The acceleration of the phenomena of drought, aridity, desertification is the consequence of the negative effects of technological progress and intensive industrialization, and which have determined climate changes, as follows:

High temperatures:

+ 38.5 degrees Celsius - July 27, 1927, Constanta;

+ 42.2 degrees Celsius - August 1945, Cernavoda;

2007- More than 70 days without precipitation with temperatures above 35 degrees Celsius:

36.8 degrees Celsius – June 23, 2007

40 degrees Celsius – July 23, 2007

36.4 degrees Celsius – August 23, 2007.

41.4 degrees Celsius - July 8, 2008, Hirsova

39.6 degrees Celsius - July 8, 2012, Adamclisi

40.4 degrees Celsius - 25 August 2012 Cernavoda,

38.9 degrees Celsius - 16.08.2008, Hirsova,

- July-August 2022, 13 mm. = 62 days

-September 18.5 mm., October 0 mm,

-November 8 mm.
-52 days Amzacea July – November 8, 2022, only 18 mm [1, 9, 20].
Multiannual average rainfalls and temperatures over 69 years in Constanta County is shown in Table 2.
From Table 2 it is easily to distinguish the differences regarding the amount of precipitations from a month to another and also of the average temperatures, whose average on the whole period of 69 years was:
- 401 mm in case of rainfalls and
-10.8^{0}C in case of temperatures.
The monthly and annual precipitation calendar at Amzacea Meteorological Station in the years 2018-2022 is presented in Table 3. The multiannual average precipitation by agricultural regions in Romania in the period 1961-1990 and 1981-2010 is presented comparatively in Table 4.

Table 2. Multiannual average rainfalls and temperatures over 69 years in Constanta County

Multiannual average over 69 years		
Month	Rainfall	Temperature
I	58.9	-0.6
II	24.0	0.7
III	25.4	4.0
IV	32.1	9.6
V	39.0	15.3
VI	47.8	19.5
VII	33.8	21.7
VIII	33.0	21.2
IX	29.9	17.0
X	34.2	11.8
XI	41.2	6.5
XII	34.7	2.1
Annual Average	401.0	10.8

Source: Valul lui Traian Research and Development Station for Agriculture, Constanta County [33].

The maps 2, 3 and 4 show the distribution in Romania's territory of the temperatures in the periods 1961-1990, 1971-2000 and 1981-2020.

Table 3. The monthly and annual precipitation calendar at Amzacea Meteorological Station in the years 2018-2022

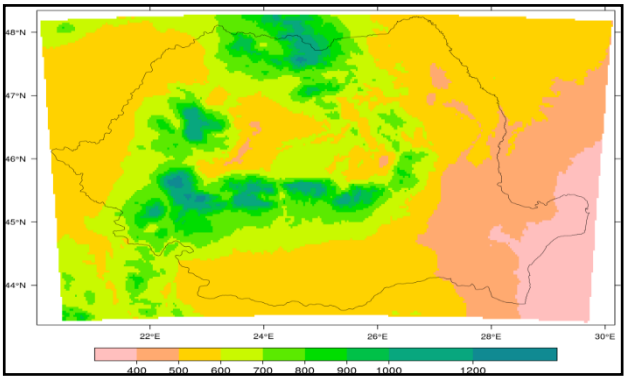
Year	**Monthly precipitations (mm)**												**Total**
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2018	63	120	68	2	92	76	147	0	3	3	57.5	47	678.5
2019	36	8	16	35.5	18	14	44	7	37	44	9.5	27.5	296.5
2020	2	50	16	15	42	24	29	0	31	18.5	21	100	348.5
2021	122.5	34	61.5	35	22	270	18.5	0	40	115	49	92.5	860
2022	19	40	42	46.5	14	45.5	10	3	69.5	0	**26**	**21**	**336.5**
Annual average	48.5	50.4	40.7	26.8	37.6	85.9	49.7	2	36.1	36.1	**32.6**	**57.6**	**503.9**

Source: Amzacea Meteorological Station [1].

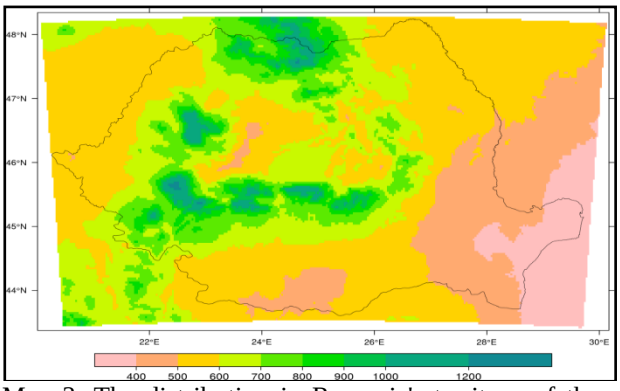
Table 4. Comparison concerning the multiannual average precipitation by agricultural regions in Romania in the period 1961-1990 and 1981-2010

	1961-1990	1981-2010
Dobrogea	417.0mm/y/poor	412.0mm/y/poor
Moldova	576.7mm/y/poor	575.9mm/y/poor
Muntenia	598.2mm/y/poor	575.7mm/y/poor
Oltenia	673.4mm/y/optimum	645.8mm/y/optimum
Crisana	669.3mm/y/optimum	668.4mm/y/optimum
Transilvania	681.5mm/y/optimum	680.0mm/y/optimum
Banat	753.2mm/y/rainy	737.8mm/y/rainy
Maramures	799.2mm/y/rainy	829.1mm/y/rainy

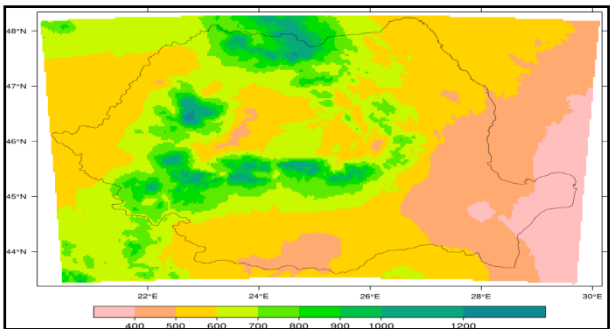
Source: Valul lui Traian Research and Development Station for Agriculture, Constanta County [33].



Map 2. The distribution in Romania's territory of the temperatures in the periods 1961-1990
Source: [22].



Map 3. The distribution in Romania's territory of the temperatures in the periods 1971-2000
Source: [22].



Map 4. The distribution in Romania's territory of the temperatures in the periods 1981-2010
Source: [22].

In Constanta county, the main cultivated crops are wheat, barley, maize, sunflower and sorghum as shown in Table 5.
In the interval 2017-2022, the cultivated area in Constanta county declined by 6.54%.
Also, a decrease in the cultivated area was noticed in case of barley, +79.34% and sorghum +10.71%. In case of the other crops it declined.
Average production per surface unit are also presented by each considered crop in Table 5, except barley, whose yield in 2022 versus 2017 increased by 12.4%, in case of all the other crops it was noticed a reduction as a consequence of the lack of irrigation and high temperatures and long and severe droughts in these years.
Sorghum is cultivated on the smallest area in Constanta county, only on155 ha in the year 2022, by 15 ha more than in 2017.
In the analyzed period, Sorghum yield varies between the minimum 843 kg/ha in the year 2020, well known for its long drought and heat waves and 3,860 kg/ha in the year 2021.

Table 5. The cultivated area and yield for wheat, barley, maize, sunflower and sorg in Constanta county in the period 2017-2022

		2017	2018	2019	2020	2021	2022	2022/2017 %
Wheat	Area (ha)	175,969	179,309	181,723	173,253	164,480	162,688	92.45
	Yield (kg/ha)	5,413	5,677	4,748	983	5,086	4,989	92.16
Barley	Area (ha)	37,006	36,213	45,092	54,709	72,091	66,368	179.34
	Yield (kg/ha)	4,475	5,204	4,754	1,065	4,949	5,030	112.40
Maize	Area (ha)	58,045	56,269	63,499	52,517	50,277	58,922	101.51
	Yield (kg/ha)	5,786	8,124	5,628	1,458	5,239	3,788	65.46
Sunflower	Area (ha)	81,318	79,822	86,928	74,538	72,265	74,005	91.00
	Yield (kg/ha)	3,180	3,715	2,660	1,115	3,411	2,381	74.87
Sorghum	Area (ha)	140	210	222	94	308	155	110.71
	Yield (kg/ha)	3,293	2,354	2,428	843	3,860	2,148	65.22
Total Constanta	Area (ha)	474,324	474,344	476,680	459,389	445,674	443,347	93.46

Source: National Institute of Statistics, NIS, 2023, www.insse.ro, Accessed on Oct. 4, 2023 [23].

RESULTS AND DISCUSSIONS

Demonstration plots are presented and commented in this paragraph of the research paper. The technical sheet demonstration plots for sorghum crop at Sport Agra Ltd, Amzacea in the year 2017 are presented in Table 6.
2017 = 12 corn hybrids in testing. Productions varied from 8,351 kg/ha Mylord to 12,027 kg/ha LG 30,315. The corn was harvested on 30 August.

The technical sheet demonstration plots for sorghum crop at Sport Agra Ltd, Amzacea in the year 2018 are presented in Table 7.

Table 6. The technical sheet demonstration plots for sorghum crop at Sport Agra Ltd, Amzacea in the year 2017

Hybrid	Previous crop	Surface (sqm)	Stand Density	Planting date	Emergence date	Yield kg/ha	Harvest date
Alize	Wheat	2,195	220,000	4 April	14 April	10,439	24 August
Foehn	Wheat	2,195	220,000	4 April	14 April	11,504	24 August
Arkanciel	Wheat	2,195	220,000	4 April	14 April	10,336	24 August
Arkanciel	Wheat	2,195	220,000	4 May	16 May	6,900	5 September
Albanus	Wheat	2,195	220,000	4 April	14 April	10,130	24 August
Typhon	Wheat	2,195	220,000	4 April	14 April	8,859	24 August
Armorik	Wheat	2,195	220,000	4 April	14 April	10,645	24 August

Source: Original conception.

Table 7. The technical sheet demonstration plots for sorghum crop at Sport Agra Ltd, Amzacea in the year 2018

Hybrid	Previous crop	Surface (sqm)	Stand Density	Planting date	Emergence date	Yield kg/ha	Harvest date
Albanus	Wheat	2,195	240,000	11 April	24 April	10,100	22 August
Foehn	Wheat	2,195	240,000	11 April	25 April	11,000	22 August
Arkanciel	Wheat	2,195	240,00	11 April	25 April	10,669	22 August
Arkanciel	Wheat	2,195	240,000	20 April	28 April	8,634	9 September

Source: Original conception.

2018. The calendar year 2018 accumulated 678.5 mm. of which in the months of full vegetation: May – 92 mm, June – 76 mm, July – 147 mm.

23 corn hybrids were tested with variations in production levels as follows: Mayflower hybrid 12,029 kg/ha and P0023 15,191 kg/ha. Corn was harvested on September 1.

The technical sheet demonstration plots for sorghum crop at Sport Agra Ltd, Amzacea in the year 2019 are presented in Table 8.

Table 8. The technical sheet demonstration plots for sorghum crop at Sport Agra Ltd, Amzacea in the year 2019

Hybrid	Previous crop	Surface (sqm)	Stand Density	Planting date	Emergence date	Yield kg/ha	Harvest date
Foehn	Wheat	560	250,000	26 March	15 April	6,907	21 August
Alize	Wheat	560	250,000	26 March	15 April	6,844	**Harvest date**
Alize 2	Wheat	560	250,000	15 April	1 May	5,513	21 August
Albanus	Wheat	560	250,000	26 March	15 April	5,323	**Harvest date**
Shamal	Wheat	560	250,000	26 March	15 April	7,034	21 August
Anggy	Wheat	560	250,000	26 March	15 April	6,273	**Harvest date**

Source: Original conception.

The technical sheet demonstration plots for sorghum crop at Sport Agra Ltd, Amzacea in the year 2021 are presented in Table 9.

Table 9. The technical sheet demonstration plots for sorghum crop at Sport Agra Ltd, Amzacea in the year 2021

Hybrid	Previous crop	Surface (sqm)	Stand Density	Planting date	Emergence date	Yield kg/ha	Harvest date
Foehn	Wheat	560	262,000	19 April	2 May	6,428	22 September
Shamal	Wheat	560	262,000	19 April	2 May	6,607	22 September
Alize I	Wheat	560	262,000	19 April	2 May	7,410	22 September
Alize II	Wheat	560	262,000	26 April	10 May	7,053	22 September
Arabesk	Wheat	560	262,000	19 April	2 May	6,339	22 September
Anggy	Wheat	560	262,000	19 April	2 May	7,410	22 September
Belugga	Wheat	560	262,000	19 April	2 May	6,964	22 September
Huggo	Wheat	560	262,000	19 April	2 May	7,500	22 September

Source: Original conception.

On June 12, 2021, at 12:15 p.m., the platform of the observation research field benefited from a torrential rain (75 mm. in 40 minutes) accompanied by hail with disastrous effects. (Photo 1). The sorghum hybrids regenerated from internode 1-2 producing the productions presented in the table. The harvest was delayed (Photo 2).

Photo 1. Torential rainfall with hail at Amzacea on June 12, 2021, 12:15 p.m.
Source: Original.

Photo 2. Regeneration of sorghum crop following the hail from June 12, 2021 to July 30, 2021
Source: Original.

The technical sheet demonstration plots for sorghum crop at Sport Agra Ltd, Amzacea in the year 2022 are presented in Table 10.

Table 10. The technical sheet demonstration plots for sorghum crop at Sport Agra Ltd, Amzacea in the year 2022

Hybrid	Previous crop	Surface (sqm)	Stand Density	Planting date	Emergence date	Yield kg/ha	Harvest date
Anggy I	Wheat	560	262,000	26 March	30 April	7,710	23 August
Anggy II	Wheat	560	262,000	8 April	4 May	7,063	23 August
Huggo	Wheat	560	262,000	26 March	30 April	6,500	23 August
Icebergg	Wheat	560	262,000	26 March	30 April	6,418	23 August

Source: Original conception.

The technical sheet demonstration plots for sorghum crop at Sport Agra Ltd, Amzacea in the year 2023 are presented in Table 11. Sorghum is one of the cereal plants that I recommend for arid areas, the plant called "desert camel" due to its resistance to drought (Amsalu Ayana et al. 1998) [2].

The botanical features that give it resistance to drought and burning is the fasciculate root that explores the soil layers between 1.25 - 1.40 meters from which embryonic roots with absorbent hairs at 40-60 cm are born. around the plant.

Table 11. The technical sheet demonstration plots for sorghum crop at Sport Agra Ltd, Amzacea in the year 2023

Hybrid	Previous crop	Surface (sqm)	Stand Density	Planting date	Emergence date	Yield kg/ha	Harvest date
Aligator	Wheat	560	262,000	10 April	6 July	1,607	30 August
Beluga	Wheat	560	262,000	10 April	2 July	1,517	30 August
Huggo	Wheat	560	262,000	10 April	5 July	2,679	30 August
Sentinel	Wheat	560	262,000	22 April	20 July	1,071	30 August

Source: Original conception.

The determinations made reflect that the volume of sorghum roots exceeds the volume of a fully developing corn plant. In the absence of precipitation during the growing season, it stops growing, resuming at the first rains.

Sorghum contains 20-40 kg of carbohydrate juice per 100 kg/stalks, which can result in cheaper fuel [4].

It is rich in amino acids and appreciated in human consumption: more than 200 million inhabitants of the planet consume sorghum in various forms. Sorghum is a basic component in fodder rations (grains and silage), and could be used in beer industries, fuel production, etc. Also, it absorbs carbon dioxide from the atmosphere. In all the years of observational research, the preceeding plant was autumn wheat, with special emphasis on weed control. Soils infested with *Sorghum halepense* were excluded.

The soils intended for the observation platforms were plowed at a depth of 23-25 cm. until September 1 and were kept clean of weeds by applying specific mechanical works and glyphosate.

The planting was carried out in all the years of observations using early and semi-early sorghum hybrids, when the soil temperature indicates 8-10ºC at a depth of 7-8 cm, the seeds being incorporated at a maximum of 4 to 5 cm.

The surface of the experimental plots varied: between the years 2013-2018 = 2,195 sqm, and between 2019-2022 = 560 sqm.

Due to the lack of moisture at the depth of incorporation of the seeds, in all the years of observation, following the temperature of the soil at the depth of incorporation of the grains, we changed the "optimal planting periods" as presented in Table 12.

Table 12. Changes in the "optimal planting periods" of sorghum

Year	Hybrid	Planting date	Yield-Kg/ha
2014	Arkanciel	9 April	9,910
2014	Arkanciel	2 May	7,610
2016	Arkanciel	4 April	10,022
2016	Arkanciel	4 May	7,810
2017	Arkanciel	4 April	10,336
2017	Arkanciel	4 May	6,900
2018	Arkanciel	11 April	10,669
2018	Arkanciel	20 April	8,634
2019	Alize	26 March	6,789
2019	Alize	15 April	5,524
2022	Anggy	26 March	7,710
2022	Anggy	8 April	7,063

Source: Own conception.

In the four years of observations 2014-2016-2017-2018, the Arkanciel hybrid planted between April 4-11 compared to the later planting, on 20.04.-02.05.-04.05, achieved higher production levels by 2,035 kg/ha, in year 2018, sown on 20.04., obtained 2,212 kg/ha, sown on 04.05., obtained 2,300 kg/ha, sown on 02.05. of 2014 and 3,436 kg/ha sown on 04.05. of the year 2017.

In order to observe the reaction of the hybrids to the change in the planting period in 2019, 2022, the Alize and Anggy hybrids were sown, as shown in Table 13, from which it can be seen that the hybrid Alize sown on 26.03. achieved a higher production level by 1,265 kg/ha compared to the same hybrid sown on 15.04.

Table 13. Changes in the planting periods for Alize and Anggy hybrids of sorghum

Year	Hybrid	Planting date	Yield-Kg/ha
2019	Alize	26 March	6,789
2019	Alize	15 April	5,524
2022	Anggy	26 March	7,710
2022	Anggy	8 April	7,063

Source: Own conception.

The hybrid Anggy in 2022 was sown on 26.03. and achieved an increase of 647 kg/ha compared to the same hybrid sown on 08.04.

The shape and size of the nutrition space were ensured by planting at a distance of 70 cm. between rows, depending on the quality certificate of each hybrid between 230,000 - 262,000 germinating grains per hectare (at 142 linear cm. 23 - 26 grains = 1 square meter). In the following years, we will carry out observations in order to determine the shape and size of the nutrition space. Compulsorily, before planting in the geographical areas of Dobrogea, the seed must be treated with thiamethoxam 8 l/to. The young sorghum seedling is highly valued by Tanymecus dilaticollis. Gyll., producing real disasters, the carbohydrate juice attracts the insect. Between 60 and 80 kg/ha a.s. were provided with planting. phosphorus and 30 kg/ha a.s. nitrogen 120 kg/ha a.s. were applied to the vegetation together with the mechanical straws. The culture was kept clean of weeds by the pre-emergence application of herbicides based on metolachlor 960 g/l, 1.5

l/ha, and in vegetation based on acid 2.4 D 600g/l, 1 l/ha.

In all the years of observations in the first phenophases of vegetation 2-6 leaves, Iit was noticed that sorghum is a very sensitive plant to weeding, having a slow growth. From this point of view, the herbicides based on 2.4 D acid do not control dicotyledonous weed species under the conditions of Amzacea.

For this reason, on this occasion, the authors suggest the approval of the Ministry of Agriculture and Rural Development of the use of herbicides based on bromoxynil 280 g/l + 2.4-D acid (ester) 280 g/l, 1 l/ha.

Economic results at Sport Agra Ltd Amzacea

Table 13 present the economic efficiency in the year 2017.

Table 14 present the economic efficiency in the year 2019.

Table 13. Economic efficiency of agricultural crops in the year 2017

	Corn	Soybean	Sunflower	Sorghum	Wheat
Mechanical works	316	318	329	269	377
Seed	125	204	149	101	92
Fertilizer	165	74	130	156	188
Pesticides	183	124	156	51	137
Total Cost/ha	789	720	764	577	797
Average Kg/ha	8,364	1,992	3,800	8,859-11,504	7,271
Price/ton	130	299	294	130	164.7
Income	1,087	595	1,117	1,151-1,495	1,197
Profit per ha Leu/Euro 4.65	298	-125	353	574-918	400

Source: Own results.

Table 14. Economic efficiency of agricultural crops in the year 2019

	Corn	Soybean	Sunflower	Sorghum	Wheat
Mechanical works	239	214	192	201	500
Seed	96	64	82	83	111
Fertilizer	266	98	232	133	112
Pesticides	148	71	150	57	111
Total Cost/ha	698	447	656	474	834
Average Kg/ha	7.050	1.433	3.431	7.034	6.690
Price/ton	142	277	279	142	162
Income	1.001	397	957	999	1.083
Profit per ha Leu/Euro 4.65	303	-50	301	525	249

Source: Own results.

Given the increasingly aggressive climate changes and the lack of irrigation, sorghum is a definite alternative to replacing corn in certain geographical areas, in non-irrigated conditions.

In Dobrogea as well as in the Romania Plain, in the south of Moldova, the areas occupied with sorghum will have to ensure the deficit of corn, by increasing the areas occupied with this crop and by increasing production levels.

In recent years, the areas occupied with corn have decreased, in 2022, only 44,300 hectares being sown in Constanta county, of which 13,000 hectares were affected by drought in a proportion of 30-60%, the production achieved being 3,771 kg/ha.

The support linked to this culture would be of real benefit to agricultural producers.

The authors hope that Europe does not turn into a museum of innovation in which the public voice is stronger than the data of scientific research.

In 2015, in Constanta county, 51,495 ha were cultivated with corn, achieving an average production of 765 kg/ha and a total production of 39,393 tons, and in 2016, 39,555 ha with a

production level of 883 kg/ha and a total production of 34,927 tons.

In 2020, 33,329 ha were affected by calamity in Constanta county, and in 2022, 13,827 ha. In the current year, the approximately 50,000 ha cultivated with corn in Constanta county were totally or partially calamity.

A simple calculation shows us that in 2016, when a total production of 34,927 tons was achieved, delivery price on 13.09. – 158 Euros (4.4488 lei) = 702.9 lei, 24,550,188 lei were obtained.

If sorghum had been cultivated, 237,330 tons could be produced with an average production level of only 6 tons/ha. 237,330 x 702.9 = 166,819,257 lei, so a loss of 142,269,069 lei - 31,979,200 Euros and the calculations can go further, especially at the level of 2023.

Sorghum is a miraculous plant. It could resist even to hail, not only to drought.

Photo 3. Planting sorghum in 2019
Source: Original.

Photo 4. Demostrative plots in 2018
Source: Original.

Photo 5. Harvesting in 2022
Source: Original.

CONCLUSIONS

The research work was focused of the improvement of technology for cultivating sorghum under the severe climate conditions in Amzacea area, at the agricultural holding Sport Agra Ltd, South Dobrogea Romania, during the period 2017-2022.

The new technologies, based on conventional agricultural system and non -irrigated land, regard the improvement of following aspects:

- Changing the planting period by approximately 25-30 days compared to the recommendations of classical technologies. In this respect, planting should start from the first decade of May in order to use the moisture in the soil layer at the depth of seed incorporation 4-5 cm.

-The use of early hybrids in order to overcome the periods of heat that in Amzacea area start from the middle of the month of June.

-The use of technological means of crop protection that include pre- and post-emergent herbicides, seed treatment prior to planting. Under these conditions of development of non-irrigated sorghum technology, we propose planting this crop 25-30 days earlier compared to classic technology. In this way, the sorghum will benefit from the water reserve accumulated during the fall of the previous year.

-The productions of the sorghum hybrids used in the observation research fields were over 10 to/ha in most of the tested hybrids.

-Sorghum could be successfully used as a complementary crop for maize, taking into account its resistance to drought and hail.

REFERENCES

[1]Amzacea Meteorological Station.

[2]Ayana, A., Bekele, E., 2004, Georgraphical patterns of morphological variations in sorghum (*Sorghum bicolor* L. Moench) from Ehiopia and Eritrea, Qualitative chanracters. Hereditas, 129(3), 195-205.

[3]Balteanu, G., 1974, Phytotechnics (Fitotehnie), In Romanian, Didactical and Pedagogical Publishing House, Bucuresti.

[4]Budescu, D., 2004, Sweetened sorghum a miraculous plant (Sorgul zaharat o planta miraculoasa), In Romanian. Biotera, No.2.

[5]COCERAL Crop Forecast - Grains JUNE 2023, http://www.coceral.com/data/1686564279Coceral_GRAINS_June%202023_EU27%2BUK.pdf, http://www.coceral.com/web/march%202022/1011306087/list1187970814/f1.html, Accessed on Oct. 4, 2023.
[6]Demeter T., 2009, General soil science (Pedologie Generala), Credis Publishing House, Bucuresti.
[7]FAOStat, 2022, www.fao.org. , Accessed on Oct 2, 2023.
[8]Filipescu, C., 1843, Great Agricultural Encyclopaedia (Marea Enciclopedie Agricola), P.A.S. Publishing House, Vol.5, p.539-540.
[9]Hera, C., 2015, Global climate changes. Care for natural resources (Schimbarile climatice globale. Grija pentru resursele naturale). In Romanian. Romanian Academy Publishing House, 419 p.
[10]Jinga, V., Vlăduț, V., Marin, E., Manole, D., 2018, Sorghum culture - a solution for Dobrogeaba agriculture. Proceedings of International Symposium, ISB-INMA TEH'2018, Agricultural and mechanical engineering, Bucharest, Romania, 1-3 November 2018, pp.951-954.
[11]Jordan, D.R., Hunt, C.H., Cruickshank, A.W., Borrell, A.K., Henzell, R.G., 2012, The relationship between the stay-green trait and grain yield in elite sorghum hybrids grown in a range of environments. Crop. Sci. 2012;52:1153–1161., doi: 10.2135/cropsci2011.06.0326.
[12]Khakifa, M., Eltahir, E.A.B., 2023, Assessment of global sorghum tolerance and climate risk, Front. Sustain. Food Syst., 23 June 2023 Sec. Climate-Smart Food Systems, Vol.7, https://doi.org/10.3389/fsufs.2023.1184373
[13]Khanthavong, P., Yabuta, S., Asai, H., Hosain, M.A., Akagi, I., Sakagami, J.-I., 2021, Root Response to Soil Water Status via Interaction of Crop Genotype and Environment, Agronomy, 11(4), 708, https://doi.org/10.3390/agronomy11040708
[14]Law No. 1/1962, regarding the establishment of the Superior Council of Agriculture and Regional and District Agricultural Councils.
[15]Manole, D., 2018, Sorghum Crop an Alternative for Dobrogea Farmers, 4th International Congress of Sorghum, Millan, Italy, Nov.8, 2018.
[16]Manole, D., Jinga, V., Giumba, A.M., Dudoiu, R., Cristea, S., 2018, Researches regarding new and improved technologies for sunflower and sorghum crops in the context of climatic changes in Dobrogea region. Proceedings of Agriculture for Life/life for Agriculture Conference, Vol.1 (1), 79-85.
[17]Manole, D., Jinga, V., Giumba, A.M., Dudoiu, R., 2018, Sorghum crop, an alternative for Dobrogea farmers in the context of climate changes, Proceedings of AGROBIOL International Conference, Edirne, Turkey, pp. 415 – 419. (2018).
[18]Manole, D., Giumba, A.M., Ganea, L., 2020, Researches and Contributions to Plant Sorghum Crop in the conditions of Climate Change, Annals of the Academy of Romanian Scientists Series Agriculture, Silviculture and Veterinary Medicine Sciences No.11, 2020.
[19]Mansano Sarto, M.V., Barbosa Borges, W.L., Bassegio, D., Rice, C., Rosolem, C.A., 2021, Maize and sorghum root growth and yield when intercropped with forage grasses, Agronomy, Soils and Environmental Quality, 113, 4900-4915.
[20]Mateescu, E., 2017, Schimbarile climatice, o noua provocare a spatiului agricol Dobrogean, Conference, 26-27 Mai 2017, Eforie Nord, Constanta County.
[21]Muntean, L.S., Solovăstru, C., Morar, G., Duda, M.M., Vârban, D.I., Muntean, S., 2008 Phytotechnics (Fitotehnie). Academic Pres, Cluj-Napoca.
[22]National Administration of Meteorology, 2023, The distribution in Romania's territory of the temperatures in the periods 1961-1990, 1971-2000, 1981-2010,
[23]National Institute of Statistics, NIS, 2023, www.insse.ro, Accessed on Oct. 4, 2023.
[24]Pochiscanu, S. F., Robu, T., Drutu, C. A., Popa, L. D., Trotus, E., 2015, Influence of temperature on the grains germination of *Sorghum bicolor L. (*Influenta temperaturii asupra germinarii boabelor de *Sorghum bicolor L.*. J. Bot., 2015.
[25]Popescu, A., Condei, R., 2014, Some consideration on the prospects of Sorghum crop, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.14(3), 295-304.
[26]Popescu, A., Dinu. T.A., Stoian, E., 2018, Sorghum -an important cereal in the world, in the EU and Romania,, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.18(4), 271-284.
[27]Romania's Statistical Yearbook 1990
[28]Sing, V., van Oosterom,E.J., Jordan, D.R., Messina, CD., Cooper, M., Hammer, G.L., 2010, Morphological and architectural development of root systems in sorghum and maize, Plant and Soil, 333, 287-299.
[29]Soil Science Office Constanta, Dobrogea soil map.
[30]Thueuen.de, Institute of Biodiversity, Comparison of root growth of maize and sorghum under climate change, https://www.thuenen.de/en/institutes/biodiversity/projects/comparison-of-root-growth-of-maize-and-sorghum-under-climate-change, Accessed on Sept. 21, 2023
[31]Trotus, E., Lupu, C., Drutu, A. C., 2015, Technologies for cultivationg some field crops in the central area of Moldova (Tehnologii de cultivare a unor plante de camp pentru zona centrala a Moldovei) In Romanian. Ion Ionescu de la Brad Publishing House, Iasi.
[32]USDA Foreign Agricultural Service, 2023, European Union sorghum area, yield and production, https://ipad.fas.usda.gov/countrysummary/Default.aspx?id=E4&crop=Sorghum, Accessed on Oct 4, 2023.
[33]Valul lui Traian Research and Development Station for Agriculture, Constanta County.
[34]Wojciechowski, T., Kant, J., 2021, How Sorghum Root Traits Can Contribute to Cereal Yield Increase, In: Cereals grain, Aakash Kumar Goyal Editor, Vol.2, DOI: 105772/intechopen.97158

[35]Zamfirescu, N., 1965, Phytotechnics (Fitotehnie), Vol. I and II, In Romanian, Agro-technica Publishing House, Bucuresti.
[36]Zhao, D., de Voil P., Rognoni, B.G., Wilkus, E., Eyre, J.X., Broad, J., Rodriguez, D., 2023, Adapting to heat stress by sowing summer grain crops early in late winter or spring. Sorghum root growth, water use and yield. bioRxIV, doi: https://doi.org/10.1101/2023.09.10.557017