The economic value of ecotypes of pearl millet *Pennisetum glaucum* and prince's feather *Amaranthus hypochondriacus* introduced and cultivated under the environmental conditions of the R. Moldova

Valoarea economică a ecotipurilor de mei african *Pennisetum glaucum* și amarant elegant *Amaranthus hypochondriacus* introduse și cultivate în condițiile Republicii Moldova

Serghei COZARI, Victor ŢÎŢEI, Mihai GADIBADI

"Alexandru Ciubotaru" National Botanical Garden (Institute),

Chişinău, 18 Padurii str., Republic of Moldova

Workshop exploratoriu "Alimentație sustenabilă în contextul schimbărilor climatice„
SMART DIASPORA 2023, Diaspora în învățământ superior, știință, inovare și antreprenoriat,
Timișoara 10-13 aprilie, 2023

Global agriculture is dependent on a relatively small number of crop species. The incorporation of neglected and underused crops, the domestication of new species would promote agricultural diversity and could provide a solution to many of the problems associated with food security, nutrition, healthcare, medicine and industrial needs. It has been well established that the species with C4 photosynthesis are more efficient during drought and other environmental stress conditions. Amaranth is one such crop, it has been used in the Americas for thousands of years, firstly collected as wild food, and then domesticated multiple times, beginning about 6,000 years ago and it continues to be used essentially worldwide, even to the present day. Amaranth grows under drought stress, can tolerate unfavorable abiotic conditions including high salinity, acidity or alkalinity, which makes this plant uniquely suitable for subsistence farming. The amaranth grains are gluten-free, contain significant amounts of high-quality protein and oils, have several health benefits like lowering cholesterol levels, protection against heart diseases, stimulation of immune system, anticancer activity, control of blood sugar level, improved condition of hypertension and anemia, anti-allergic and antioxidant activity, etc., due to the presence of some bioactive components. Amaranth has high potential can be considered an alternative multipurpose crop in most parts of the world (DAS 2016; SORIANO-GARCÍA et al., 2018).

Amaranthus hypochondriacus **L. (syn.** ***A. anardana*** **Buch;** ***A. aureus*** **Besser;** ***A. flavus*** **L.;** ***A. frumentaceus*** **Buch.-Ham. ex Roxb;** ***A. leucocarpus*** **S. Watts) is known as the 'Prince's feather' or 'Prince-of-Wales feather' due to its ornate and vibrant inflorescence, native to southwestern North America, is a vigorous plant, with erect, annual growth that grows between 40 and 200 cm in height, sometimes even up to 250 cm. The stem is generally branched, mainly at the inflorescence level. The leaves are green in color, with possible more or less intense shades of purplish color, ovate lanceolate shape, carried by long petioles. Inflorescences predominantly terminal, up to 45 cm long, often with few spikes at distal axils stiff, erect, dark red, purple, or deep beet-red, less commonly yellowish or greenish, leafless at least in distal part, usually robust. Fruit an obovoid to rhombic capsule 1.5–2 mm long, circumscissile, with a short beak, 1-seeded. Seed is obovoid to ellipsoid, compressed, 1 mm long, whitish to yellowish or blackish. Seedling with epigeal germination, hypocotyl 10–12 mm long, cotyledons about 18 mm × 5 mm, fleshy, petiolate. Chromosome complement is 2n = 32.**

Amaranthus hypochondriacus **is studied and cultivated as ornamental, pseudocereal, fodder and energy crop in many regions of the world. The goal of this research was to evaluate the quality of the seeds and phytomass of the non-native species** ***Amaranthus hypochondriacus*** **and the potential of its use as feed, fodder and feedstock for the production of renewable energy in the Republic of Moldova.**

Amaranthus hypochondriacus

MATERIALS AND METHODS

The introduced ecotype of non native species pearl millet, *Pennisetum glaucum* and amaranth *Amaranthus hypochondriacus* which were introduced and cultivated in the non-irrigated experimental plot of the National Botanical Garden (Institute) Chişinău N 46°58′25.7″ latitude and E 28°52′57.8″ longitude, served as subject of the research and the traditional crop – corn *Zea mays,* common oat *Avena sativa,* were used as control variants. The green mass of *Pennisetum glaucum, Amaranthus hypochondriacus* and *Avena sativa* was mowed in flowering stage (late July), but the *Zea mays* – in kernel milk-wax stage (middle August). The green mass was shredded and compressed in well-sealed containers. After 45 days, the containers were opened, and the organoleptic assessment and fermentation quality of the silage determined in accordance with the Moldavian standard SM 108. Some assessments of the main biochemical parameters: crude protein (CP), crude fibre (CF), ash, acid detergent fibre (ADF), neutral detergent fibre (NDF) and acid detergent lignin (ADL), total soluble sugars (TSS), digestible dry matter (DDM), digestible organic matter (DOM) have been determined by near infrared spectroscopy (NIRS) technique PERTEN DA 7200 of the Research and Development Institute for Grassland Braşov, Romania. The concentration of nitrogen free extract (NFE), hemicellulose (HC) and cellulose (Cel), the digestible energy (DE), the metabolizable energy (ME) and the net energy for lactation (NEl) were calculated according to standard procedures.

The biochemical methane potential (Ym) were calculated according to Dandikas et al. 2015

The biochemical composition of the grains: crude protein (CP) – by Kjeldahl method; crude fat (EE) – by Soxhlet method; crude cellulose (CF) – by Van Soest method; calcium concentration – using the atomic absorption spectrometry method and phosphorus – using the spectrophotometric method. Theoretical Ethanol Potential (TEP) was calculated according to the equations of GOFF et al., 2010 based on conversion of hexose (H) and pentose (P) sugars:

H = [%Cel+(%HC x 0.07)]x 172.82; P = [%HC x 0.93] x 176.87 ; TEP = [H + P] x 4.17.

The physical and mechanical properties of dry biomass were determined according to the European Standards, at the State Agrarian University of Moldova: SM EN ISO 18134; SM EN ISO 18125; SM EN ISO 17827; SM EN ISO 17828, SM EN ISO 18847, automatic calorimeter LAGET MS-10A with accessories was used for the determination of the calorific value.

The briquetting was carried out by hydraulic piston briquetting press BrikStar model 50-12 (Briklis).


green mass
silage


green mass


silage

RESULTS AND DISCUSSIONS

Some agro biological peculiarities of the studied species

Indices	*Pennisetum glaucum*	*Sorghum sudanense*
Plant height, cm	145	212
Stem thickness, mm	27	7
Leaf fresh mass, g/tiller	64.7	12.5
Leaf dry matter, g/tille	14.6	3.2
Stem fresh mass, g/tiller	60.2	33.1
Panicle fresh mass, g/tiller	37.4	3.0
Leaves + panicle content, %	74.6	34.5
The fresh mass yield, kg/m^2	3.65	2.79
The dry matter yield, kg/m^2	0.86	0.72

Indicators	*Amaranthus hypochondriacus*	*Zea mays*
Sowing	05.05	05.05
Emergence of plantlets	09.05	12.05
Inflorescence initiation period	20.07	16.07
Plant height, cm	160	239
The total yield :		
- fresh mass, kg/m^2	6.85	4.09
- dry matter, kg/m^2	1.04	1.22
The leaf content in biomass, %	54.0	27.8

The biochemical composition, the nutritive and the energy value of the green mass

Indices	*Amaranthus hypochondriacus*	*Zea mays*
Crude protein, g/kg	172	62
Acid detergent fibre, g/kg DM	330	310
Neutral detergent fibre, g/kg DM	462	520
Acid detergent lignin, g/kg DM	55	51
Total soluble sugars, g/kg DM	68	210
Crude ash, g/kg DM	88	60
Digestible dry matter, %	57.1	72.3
Digestible organic matter, %	51.4	68.3
Digestible energy, MJ/ kg	12.45	12.72
Metabolizable energy, MJ/ kg	10.22	10.75
Net energy for lactation, MJ/ kg	6.23	6.46
Relative feed value	127	116
Potential crude protein, kg/ha	1910	760

The biochemical composition, the nutritive and the energy value of the green mass

Indices	*Pennisetum glaucum*	*Sorghum sudanense*
Crude protein, g/kg DM	112	85
Crude fibre, g/kg DM	327	392
Ash, g/kg DM	73	95
Acid detergent fibre, g/kg DM	332	413
Neutral detergent fibre, g/kg DM	591	656
Acid detergent lignin, g/kg DM	43	41
Total soluble sugars, g/kg DM	182	138
Cellulose, g/kg DM	289	372
Hemicellulose , g/kg DM	259	243
Dry matter digestibility, %	65.5	51.7
Organic matter digestibility, %	60.6	50.6
Digestible energy, MJ/kg DM	12.42	10.39
Metabolizable energy, MJ/kg DM	10.19	8.52
Net energy for lactation, MJ/kg DM	6.27	5.28

Biochemical composition and economical value of silage

Indices	*Pennisetum glaucum*	*Sorghum sudanense*
pH index	4.23	3.82
Content of organic acids, g/kg DM	24.5	30.0
Total acetic acid, g/kg DM	7.1	4.4
Total butyric acid, g/kg DM	0.0	0.2
Total lactic acid, g/kg DM	17.7	28.4
Acetic acid, % of organic acid	28.63	14.67
Butyric acid, % of organic acids	0.00	0.66
Lactic acid, % of organic acids	71.37	84.67
Crude protein, g/kg DM	112	57
Crude fibre, g/kg DM	322	392
Ash, g/kg DM	85	109
Acid detergent fibre, g/kg DM	337	402
Neutral detergent fibre, g/kg DM	595	652
Acid detergent lignin, g/kg DM	29	39
Total soluble sugars, g/kg DM	182	108
Cellulose, g/kg DM	308	363
Hemicellulose , g/kg DM	258	250
Dry matter digestibility, %	73.6	57.5
Organic matter digestibility, %	65.4	53.8
Digestible energy, MJ/kg DM	14.31	11.43
Metabolizable energy, MJ/kg DM	11.74	9.38
Net energy for lactation, MJ/kg DM	7.07	5.54

Biochemical composition and ecomical value of silage

Indices	*Amaranthus hypochondriacus*	*Zea mays*
pH index	3.86	3.61
Content of organic acids, g/kg	19.2	32.8
Acetic acid, g/kg	5.8	3.3
Butyric acid, g/kg	0.0	0.0
Lactic acid, g/kg	13.4	29.5
acetic acid, % of organic acids	30	10
butyric acid, % of organic acids	0	0
lactic acid, % of organic acids	70	90
Crude protein, g/kg	167	53
Acid detergent fibre, g/kg DM	348	303
Neutral detergent fibre, g/kg DM	516	514
Acid detergent lignin, g/kg DM	45	46
Total soluble sugars, g/kg DM	12	276
Crude ash, g/kg DM	123	50
Digestible dry matter, %	61.8	72.4
Digestible organic matter, %	51.3	68.5
Digestible energy, MJ/ kg	12.2	12.82
Metabolizable energy, MJ/ kg	10.2	10.52
Net energy for lactation, MJ/ kg	6.03	6.54
Relative feed value	111	118
Potential crude protein, kg/ha	1650	620

The biochemical composition and the biomethane production potential of studied substrates

Indices	*Pennisetum glaucum*	*Sorghum sudanense*
green mass substrates		
Ratio carbon/nitrogen	29	37
Cellulose, g/kg DM	289	372
Hemicellulose, g/kg DM	259	243
Acid detergent lignin, g/kg DM	43	41
Biogas potential, L/kg VS	630	622
Biomethane potential, L/kg VS	337	334
silage substrates		
Ratio carbon/nitrogen	28	54
Cellulose, g/kg DM	322	363
Hemicellulose, g/kg DM	258	250
Acid detergent lignin, g/kg DM	29	39
Biogas potential, L/kg VS	673	584
Biomethane potential, L/kg VS	360	293

The biochemical composition and the biomethane production potential of studied substrates

Indices	*Amaranthus hypochondriacus*	*Zea mays*
Nitrogen, g/kg DM	26.72	8.51
Carbon, g/kg DM	48.77	54.00
Ratio carbon/nitrogen	18.25	63.45
Cellulose, g/kg DM	303	257
Hemicellulose, g/kg DM	158	211
Acid detergent lignin, g/kg DM	45	46
Biogas potential, L/kg VS	590	599
Biomethane potential, L/kg VS	302	306

The biochemical composition of the studied grains

Indices	*Pennisetum glaucum*	*Avena sativa*
Crude protein, % DM	13.28	10.30
Crude fats, % DM	5.85	4.46
Crude cellulose, % DM	2.10	13.76
Nitrogen free extract, % DM	76.41	62.69
Soluble sugars, % DM	2.61	-
Starch, % DM	30.46	-
Ash, % DM	2.36	3.74
Nutritive units/ kg DM	1.09	1.00
Metabolizable energy, MJ/kg DM	11.78	10.76
Calcium, % DM	0.06	-
Phosphorus, % DM	0.07	-

Indices	*Amaranthus hypochondriacus*	*Zea mays*
Crude protein, g/kg DM	180.8	83.5
Crude fats, g/kg DM	82.3	43.7
Crude fibre, g/kg DM	53.2	27.5
Nitrogen free extract, g/kg DM	657.4	829.6
Ash, g/kg DM	26.3	15.7
Calcium, g/kg DM	2.5	2.5
Phosphorus, g/kg DM	2.0	0.3

The biochemical composition and the economic value of the straw

Indices	*Pennisetum glaucum*	*Avena sativa*	*Festuca arundinacea*
Crude protein, g/kg DM	57	62	68
Crude fibre, g/kg DM	487	467	471
Minerals, g/kg DM	113	82	96
Acid detergent fibre, g/kg DM	530	499	518
Neutral detergent fibre, g/kg DM	823	800	754
Acid detergent lignin, g/kg DM	74	56	75
Cellulose, g/kg DM	456	443	443
Hemicellulose, g/kg DM	293	301	236
Digestible dry matter, g/kg DM	476	500	485
Digestible energy, MJ/ kg	9.65	10.09	9.82
Metabolizable energy, MJ/ kg	7.92	8.28	8.07
Net energy for lactation, MJ/ kg	3.95	4.30	4.08
Ratio carbon/nitrogen	54	51	46
Biomethane potential, L/kg VS	282	308	275
Hexose sugars, g/kg	82.35	80.20	79.41
Pentose sugars, g/kg	48.20	49.51	38.82
Theoretical ethanol potential, L/t	544.4	540.9	493.0

The cell wall composition of dehydrated stalks and theoretical ethanol potential of the studied species

Indices	*Amaranthus hypochondriacus*	*Zea mays*
Acid detergent fiber, g/kg	477	499
Neutral detergent fiber, g/kg	680	749
Acid detergent lignin, g/kg	73	87
Cellulose, g/kg	404	417
Hemicellulose, g/kg	203	250
Hexose sugars, g/kg	72.3	75.1
Pentose sugars, g/kg	33.4	41.1
Theoretical ethanol potential	441	485

Some physical and mechanical properties of biomass and briquettes

Indices	*Amaranthus hypochondriacus*	*Zea mays*
Ash content of biomass,%	2.3	4.4
Gross calorific value of biomass, MJ/kg	18.0	17.8
Bulk density of chopped chaffs, kg/m^3	165	87
Bulk density of milled chaffs, kg/m^3	188	100
Specific density of briquettes, kg/m^3	901	923
Bulk density of briquettes, kg/m^3	516	501
Net calorific value of briquettes, MJ/kg	14.4	14.0

CONCLUSION

The introduced ecotype of pearl millet, *Pennisetum glaucum* and amaranth *Amaranthus hypochondriacus* under the climatic conditions of the Republic of Moldova were characterized by high growth rate, the productivity of pearl millet reached 3.65 kg/m2 green mass or 0.86 kg/m2 dry matter and amaranth productivity is about 6.85 kg/m2 green mass or 1.04 kg/m2 dry matter.

The green mass and silage prepared from pearl millet and amaranth contain a lot of nutrients, which make them suitable to be used as a part of diverse livestock diets.

The green mass and silage may be used as substrates for biomethane production, and straw- for cellulosic bioethanol production as renewable energy.

Pearl millet, *Pennisetum glaucum* and amaranth *Amaranthus hypochondriacus* can be exploited in many ways: as grain, fodder and as feedstock in the production of renewable energy.

The study has been carried out in the framework of the projects:
20.80009.5107.02 *"Mobilization of plant genetic resources, plant breeding and use as forage, melliferous and energy crops in bioeconomy"*
20.80009.5107.12 *"Strengthening the "food-animal-production" chain by using new feed resources, innovative sanitation methods and schemes"*

Vă mulțumim pentru atenție!
Vă invităm să vizitați Grădina Botanică Naţională
(Institut) „Alexandru Ciubotaru” din Chișinău, Universitatea de Stat din Moldova
Thank you for your attention!