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Mohunnad Massimi
Ministry of Agriculture, Jordan

Moh`d K. Al-Rifaee
National Agricultural Research Center - NARC

Abdullah Dakheel
International Centre for Biosaline Agriculture

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Salt-tolerant Triticale (X *Triticosecale* Witt) Cultivation in Jordan as a New Forage Crop

Mohunnad Massimi[1*], Moh`d Al-Rifaee[1], Jamal Alrusheidat[1], A. Al-Dakheel[2], Faddel Ismail[1] and Yousef Al-Ashgar[1]

[1]National Center for Agricultural Research and Extension (NCARE), Baqa`, Jordan.
[2]International Center for Biosaline Agriculture (ICBA), Dubai, United Arab Emirates.

Authors' contributions

This work was carried out in collaboration between all authors. Author MM designed the study, wrote the protocol and wrote the first draft of the manuscript. Author JA enriched the literature topics. Authors MM and FI managed the analyses of the study. Authors MAR and AAD coordinated the project activities. Author MM performed the statistical analysis. Author YAA supervised experiments in Azraq area. All authors read and approved the final manuscript.

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ABSTRACT

The impact of climate change and global warming on food and feed crops production is reported in Jordan; a country where dry areas constitute about 90% of its land. The remaining arable areas (under rain fed or irrigated farming system) are decreasing due to urbanization, land fragmentation, drought, water scarcity, underground water over pumping and salinity. There is an urgent need for more tolerant crops that are capable to stand and cope with adverse climatic conditions and for diversification of crops in the farming systems.
The purpose of this work was to introduce a new forage crop suitable for small holders suffering from soil and, or water salinity. Triticale (X *Triticosecale* Witt) lines were evaluated for salt (soil and

**Corresponding author: E-mail: massimi1980@gmail.com;*

water) tolerance at Al-Khaledeya station and the most promising line was introduced to farmers' fields. Two-year field observations were conducted to study the effect of crop genotype on total yield. Two crops (triticale "Syria-1" cultivar, and barley "ACSAD 176" cultivar) were used in these trials, seeds from different crops were planted in both growing seasons of 2011-2012, and 2013-2014 at Azraq saline region (16.7 dS/m, and 2.1 dS/m in soil and water, respectively) field, and at Hashmyahh treated waste water region (3.17 dS/m, and 1.98 dS/m in soil and water, respectively). The grain and straw yield were compared with barley in the same region. Grain and straw chemical traits were evaluated in the laboratory by measuring Protein, fibers, neutral detergent fiber (NDF) and acid detergent fiber (ADF) percentages for the cultivated triticale in both regions of one season 2011 - 2012. Results indicated that triticale had positive effect on total yield in the salty region, triticale grains neutral detergent fiber percentage was 64.42% and was higher than that of triticale grains under treated waste water. In addition, acid detergent fiber percentage in the grains of the triticale was 12.54% and was lower than acid detergent fiber percentage (21.02%) of triticale grains grown under treated waste water. Triticale was adopted as a new forage crop by the farmers and its cultivation was disseminated in the salty regions. The total cultivated area to triticale in 2011 – 2015 expanded up to 46.6 ha, and this crop became commercialized and part of the seed production market in Jordan.

Keywords: Triticale; salt tolerant crops; farmers; grain yield; chemical composition.

1. INTRODUCTION

In the 1950s, plant geneticists and breeders hoped to produce a cereal that has a superior yield, disease resistant and hardiness from the cross fertilization of wheat and rye, the hardiness and disease resistance of rye with milling and baking qualities of wheat. Two decades later, triticale, as commercial variety became available. The other big advantages of the new breed are rich nutritional credentials as reported by [1], which summarized them in four major points; a 13% of protein, richness in vitamins, and most importantly, thiamin and folate, a good source of phosphorus, magnesium and manganese. A final plus is a lower content in protein complex which forms gluten. In addition to the mentioned advantages of triticale, it is highly adaptable forage for grazing, produce good silage with high protein and well digestibility boot-stage hay, It is excellent forage for dairy cows, beef cows, and dairy heifers. High protein, digestibility, and significantly higher yields than other boot-stage cereal grains [2]. Due to its robust agronomic characteristics such as long straw, triticale is rapidly increasing in popularity among farmers as a financially better option [3].

1.1 Uses of Triticale

When triticale was produced, breeders hoped that the new crop will give higher yield than other cereal grains under less than ideal growing conditions. The benefits of triticale exceeded the expected results for both the human and animal consumptions. For human consumption, triticale quality evaluations, such as for milling and baking, show that it is poorer to bread-making wheat and to durum wheat for macaroni, but superior to rye [4]. As a feed grain, triticale has high potential as a feed grain with a protein content lines has ranged from 10 to 20% on a dry weight basis. On the other hand, the amino acid composition of the protein in triticale is similar to wheat, but slightly higher in lysine. For poultry, triticale trials with turkeys and laying hens at North Dakota State University showed it approximately equal to durum wheat for energy content, gaining weight and feed use efficiency.

Other studies revealed the chemical composition of major forage cereals in Jordan, the following table illustrated forage quality of forage winter crops [5]. It is obvious that the triticale grains have the highest percentage of protein comparing with other forages, while its fiber content is the lowest. When it comes to the dry matter of forages, triticale grains does not differ from other forages. It is slightly less than barley, oat hay and wheat straw. Triticale straw have the highest dry matter percentage.

During the last decade or so, much experimentation has focused on increasing the output of rain fed cereal crops in semiarid zones. While barley (*Hordeum vulgare* L), bread wheat (*Triticum aestivum* L. spp *aestivum*) and durum wheat (*Triticum turgidum* L. spp *durum*) are the dominant cereals, attention has centered on triticale (X *Triticosecale* Witt), a crop deemed to have considerable potential in commercial agriculture.

Table 1. Dry matter, crude protein and crude fiber composition of local forage crops in Jordan

Forage	Dry matter *DM %*	Crude protein % *CP%*	Crude fiber % *CF%*
Barley straw	92	4	42
Barley grains	87	12	5
Oat hay	91	78	32.7
Oat grains	91	11.7	12.5
Triticale straw	93	2.8	39.8
Triticale grains	89	13.4	4
Wheat straw	93	3	36
Wheat grains	89	12	--

Salinity in soil or water is one of the major stresses that limit traditional cereal growth and productivity worldwide. Triticale (X *Triticosecale* Witt) is one of the most successful man-bred cereal that was crossed to obtain a cereal that combines unique grain quality of wheat (*Triticum* spp) parent with tolerance to abiotic and biotic stresses of rye (*Secale* spp) parent [6]. Triticale seems to be an interesting alternative to other cereals, particularly bread wheat, in environments where growing conditions are unfavorable or in low-input systems [7].

Moustafa et al. [8] documented that water resources in Jordan consist mainly of ground and surface water. Renewable water resources are estimated to be 780 Mm^3/ year, including ground water of 275 Mm^3/year distributed among 11 basins and usable surface water of 505 Mm^3/year distributed among 15 catchment basins. The most important suppliers of surface water are the Zarqa and Yarmouk rivers. The water quality of Zarqa river has deteriorated because of waste water effluent. 67 saline water springs have been identified in Jordan: 23 in Jordan river basin, 33 in the Dead Sea basin, 8 in the Wadi Araba basin, 1 in Azraq basin, and 2 in the Al-Jafr basin. The total average discharge was estimated to be about 46 Mm^3/year. Azraq basin salinity 300-815 mg/L of total dissolved salts, while the Zarqa basin (Hashmyahh region) has a total dissolved salts of a range 930-2100 mg/L [8]. Furthermore, soil salinity in Jordan valley, where more than 60% of Jordan agricultural production is, 63% of soils are indeed saline, in which 46% of soils are moderately to strongly saline [9].

In Jordan, the newly-introduced cereal crop is seen as having a complementary role to the major cereals, especially in the semiarid zones. [10] concluded that triticale total biological yield ranges from 12-16 ton/ha according to a range of water salinity. [11] reported that fall planted winter cereals such as triticale produce higher forage biomass than spring types. [12] reported one of the very important triticale trials that have been conducted to compare a high salinity-tolerant triticale, with other cereals, triticale generally tolerated salinity at a higher threshold and responded well to soil salinity at 6.1 dS/m ECe, i.e. up to 100% yield in comparison to corn (grains) at 2.7 dS/m, Rye at 5.9 dS/m and wheat at 4.7 dS/m.

Although grain protein composition depends primarily on genotype, it is significantly affected by environmental factors and their interactions [13]. Temperature, moisture and soil fertility, particularly nitrogen, are among the environmental factors that most influences grain protein content in cereal, mainly by affecting grain yield [14]. There has been relatively limited investigation regarding the influences of salinity on grain quality in cereal crops. Previous research in durum wheat showed differential response of salt tolerant and salt sensitive cultivars to salinity stress in view of grain quality with only salt-tolerant cultivar being significantly affected [15]. They found a positive effect of salinity on ash content and SDS sedimentation volume and a negative effect on beta carotene content in grain.

Several cultural practices might be followed to cope with the salinity problem like growing salts absorbable plants, crop rotation, using soil organic amendments, using treated waste water in irrigation, and growing salt tolerant crops. Planting salt tolerant crops could be a durable practice to soil salinity problem, as well as relatively productive within the same growing unit in comparison to traditional intolerant plants, thus more economically viable.

These encouraging results suggested a comparison of triticale and barley crops under saline conditions in irrigated farms conditions.

The foregoing trial on a representative salt tolerant triticale in saline soil in Azraq region was both diagnostic and demonstrational, triticale was adopted as a new forage crop by the farmers and its cultivation was disseminated in the salty regions.

2. MATERIALS AND METHODS

2.1 Plant Materials and Growth Conditions

The main purpose of the study was to introduce a new crop, triticale, to farmers and to show the advantages of growing the crop in farmers' areas. The study also sought to assess the local farmers' response towards the overall situation of having the new crop. The study was conducted to assess the knowledge about the new crop and whether if farmers were familiar with its various advantages among the local farmers of the area. The new lines of Triticale (X *Triticosecale* Witt) were evaluated first for salinity tolerance (soil and water tolerance) at a research station belongs to the National Center for Agricultural Research and Extension (NCARE). In a later stage, the most promising line was selected and introduced to farmers in a saline region, and specifically, in two areas characterized by low rainfalls, salty soil and close to semi arid conditions.

Seeds were planted in the fields in two growing seasons (2011-2012, and 2013-2014). Crop cultivars were randomly assigned to the experimental units which consisted of a single 0.1 ha. 11.5 Kg of Syria-1 triticale and 10 Kg of ACSAD 176 barley seeds were hand planted at a planting depth of approximately 12-cm.

Field records were determined using a traditional crop barley, during 2011-2012, and 2013 – 2014 growing seasons, barley as a salt tolerant crop was included as control. Plant materials were grown in two growing seasons and separate experiments under salt stressed conditions at the farmer field of Azraq region, 105 km east of Amman, close to the Iraqi borders, 31°50 N 36°49 E, 530 m asl). Azraq basin water salinity 300-815 mg/L. The soil at this trial site is clay loam, typic Badia of the semi-arid area EC= 16.7 dS/m. Mean annual precipitation was 25.5 mm. Each experiment was conducted, at the salt stressed; irrigated water with an EC of 2.1 dS/m was used until spring season stage in a rate of 1500 m^3/0.1 ha/Season. Other two seasonal separate experiments conducted under treated waste water conditions at the farmer field of Hashmyahh region, Jordan (115 km north of Amman, 550 m asl). Zarqa (Hashmyahh) water salinity 930-1230 mg/L, the soil at this trial site is silt clay, EC= 3.17 dS/m. Each experiment was conducted, at the treated waste water area; irrigated water with an EC of 1.98 dS/m was used until spring season stage in a rate of 810 m^3/0.1 ha/Season.

Field production tagged to record the data for grains and green fodders per hectare at harvesting. Both the grain yield and the green fodder yield per 0.1 ha was determined by harvesting all planted areas expressed in ton/ha.

2.2 Grain and Straw Forage Quality Traits

At the harvest maturity of triticale, five random samples were collected to measure forage quality traits. Crude protein %, crude fiber %, neutral detergent fiber %, and acid detergent fiber % were evaluated. The experimental procedures used were the drying of each plant grains and straws. Four grams of dried grains and four grams of dried straw were weighed and tested. Ultimately, the percentage of crude protein, crude fiber, neutral detergent fiber, and acid detergent fiber in the flour was calculated. Each parameter percent was expressed by a mean of two samples from each the powder of each plant part.

An analysis for two samples assuming equal variance was made for the measured parameters using t-test, at an alpha level of 0.05.

3. RESULTS AND DISCUSSION

Result in (Table 2) showed an influence of genotype on crop yield, a difference was found for triticale collective dry grains and straw among barley for the same location (Table 2). These results confirm the yield superiority of triticale compared to bread wheat in saline soil reported by Ortiz-Monasterio et al. [16] **,** as well as triticale superiority yield to durum and bread wheat in normal soils. Moreover, [17] concluded that triticale out-yielded both barley and oat. The results in (Graph 1) indicated those differences for collective dry grains and straw yields (ton/ha) of harvested triticale and barley for two locations among two growing seasons (2011-2012), and (2013- 2014).

It was stated by [18] that triticale had a similar mean grain yield 3842 kg/ha to that of bread wheat, but was significantly higher yielding than barley or durum wheat (5 and 7%, respectively). The trials showed that, for yield, triticale performed very well in comparison with barley. In addition, [11] reported that fall planted winter cereals such as triticale produce higher forage biomass.

The crude protein and fiber percentages of triticale produced in Azraq region on (2011-2012) as well neutral detergent fiber %, and acid detergent fiber % were evaluated at the National Center for Agricultural Research and Extension (NCARE) laboratory, Amman. It was compared with analysis of triticale produced in Hashmyahh region on the same season (2011-2012). Data for the above parameters in Azraq and Hashmyahh areas are presented in Table 3.

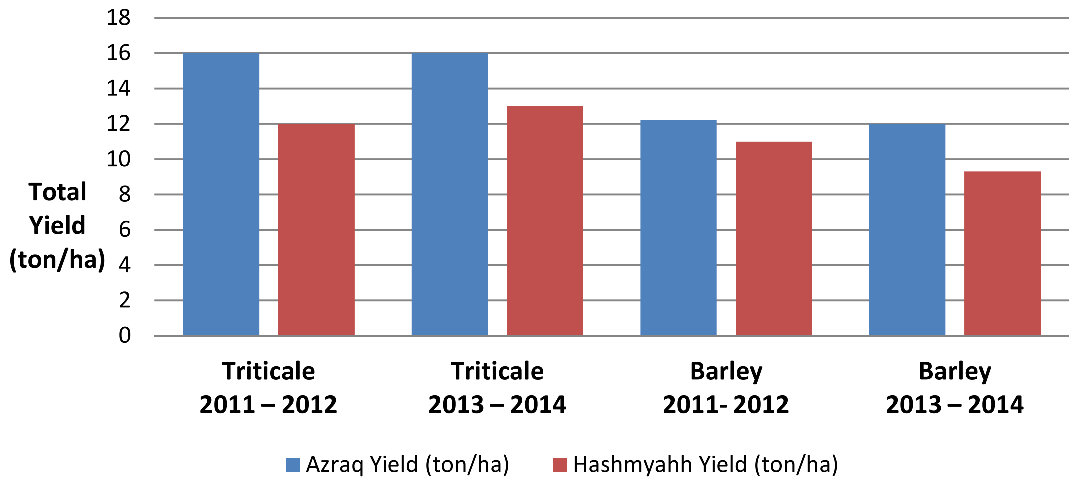
The second trial had different soil salinity. Both locations appeared to perform differently. This was exemplified by a soil salinity of 3.17 dS/m at the second site. The chemical composition of triticale in saline area trial had greater neutral detergent fiber and lower acid detergent fiber in grains than the other site. Moreover, Azraq saline soil site trial was lower than the second trial for crude protein and fiber percentages components measured. Acid detergent fiber is the fibrous component represents the least digestible fiber portion of forage. Forages with higher acid detergent fiber are lower in digestible energy than forages with lower acid detergent fiber. Neutral Detergent Fiber is the most common measure of fiber used for animal feed analysis. The level of neutral detergent fiber in the animal ration influences the animal's intake of dry matter and the time of rumination. The concentration of neutral detergent fiber in feeds is negatively correlated with energy concentration.

Table 2. Collective dry grains and straw yield of harvested triticale and barley in Azraq, and Hashmyahh trial sites during 2011-2012, and 2013-2014

Growing season	Crop	Azraq yield (ton/ha)	Hashmyahh yield (ton/ha)
2011 – 2012	Triticale	16	12
2013 – 2014	Triticale	16	13
2011- 2012	Barley	12.2	11
2013 – 2014	Barley	12	9.3
Comparison between two crops for same location	*t-statistical*	*39*	*2.382994595*
	t-critical (One-tail)	*2.919986*	
	t-critical (Two-tail)	*4.302653*	

Table 3. Crude protein, crude fiber, neutral detergent fiber, and acid detergent fiber percentages for triticale in Azraq, and Hashmyahh trial locations 2011- 2012

Location	Replication	Sample	*CP %*	*CF %*	*NDF %*	*ADF %*
Azraq	1	Triticale grains	6.1	9.53	64.8	12.34
Azraq	2	Triticale grains	6.53	9.6	64.04	12.74
Hashmyahh	1	Triticale grains	10.5	19.61	52.25	20.93
Hashmyahh	2	Triticale grains	10.5	19.61	52.27	21.1
Comparison between grains for two locations		***t-statistical***	*-19.4651*	*-287*	*31.98893*	*-38.999*
		t-critical (One-tail)		*2.919986*		
		t-critical (Two-tail)		*4.302653*		
Azraq	1	Triticale straw	1.74	34.66	69.94	38.26
Azraq	2	Triticale straw	1.74	35	70.14	38.37
Hashmyahh	1	Triticale straw	3.35	38.05	74.36	40.71
Hashmyahh	2	Triticale straw	3.49	38.13	74.05	41.04
Comparison between straw for two locations		***t-statistical***	*-24*	*-18.6667*	*-22.5796*	*-14.719*
		t-critical (One-tail)		*2.919986*		
		t-critical (Two-tail)		*4.302653*		



Graph 1. Collective dry grains and straw yield of harvested triticale and barley in Azraq and Hashmyahh trial sites during 2011 - 2012, and 2013 - 2014

Greater neutral detergent fiber and acid detergent fiber of ensiled triticale versus barley and oat silages have been previously observed by [17]***.***

4. CONCLUSIONS

Triticale grown in saline soil performed very well, and on the basis of yield and chemical composition, produced suitable forage source for neutral detergent and acid detergent fibers. However, on the basis of analysis for crude protein, triticale grown in saline soils was less acceptable than triticale grown under treated waste water.

Saline conditions are common in Jordan and these results suggest that triticale might be a productive crop in these areas. Adoption practiced in 2013 via Farmers' Field Schools (FFS) also. It was recommended that more research is required to determine the relationship between forage quality and livestock uses of triticale as a feed crop.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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