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How Do Older Wheat Cultivars Compare to Modern Wheat Cultivars Currently on the Market in South Africa?

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Abstract

Bread wheat is cultivated globally and is currently the major staple crop in temperate zones. After maize, wheat is the most important grain crop, cultivated in South Africa. 'Ancient' wheat landraces were cultivated commonly in the past, but are today only grown on a small area in some countries for traditional foods. Because they have been proposed to be rich sources of bioactive components these historical wheat landraces, compared to current wheat cultivars on the market, are believed to produce higher value food products with enhanced health benefits. In South Africa there has been a renewed interest in older wheat cultivars, such as Witwol, by farmers producing wheat for niche markets. Bolane and Makaloate are cultivars planted traditionally in the highlands of Lesotho. To determine how these older and traditional cultivars compare with modern wheat cultivars on the market, Witwol, Bolane and Makaloate were compared to dry land wheat cultivars, currently on the market in South Africa, with regard to Russian Wheat Aphid (RWA) resistance, yield, hectolitre mass, protein content, mixing time and loaf volume. Since these 'heritage' and traditional wheat cultivars are low yielding in comparison with modern wheat cultivars on the market and not adapted to modern agricultural practices, they will not contribute to feeding the growing world population, but the re-introduction to the market and use of 'heritage' and traditional wheat cultivars might have a place in markets where its holistic use as crop is a viable option for producers, millers and bakers who cater for specific consumer markets. Encouraging the cultivation of these cultivars will also increase the biodiversity of our food products.

Keywords

Bread wheat, *Triticum aestivum*, Ancient cultivars, Yield, Baking quality, Landraces

Introduction

Bread wheat, *Triticum aestivum*, is cultivated globally and is currently the major staple crop in temperate zones. Bread wheat accounts for 95% of wheat grown annually, with 'pasta' or 'durum wheat', *Triticum turgidum* var. *durum*, making up the rest of wheat cultivation [1]. After maize, wheat is the most important grain crop, cultivated in South Africa. Over time, there has been considerable change in variety of bread wheat as a result of the need to improve yield potential [2], resistance to biotic and abiotic stresses [3] and nutritional and processing quality [4]. The need for increased food production in an agricultural environment where land and water are becoming increasingly scarce resources is driving the selective breeding to improve wheat cultivars. In this regard the main role players in South Africa are ARC-Small Grains (established in 1976 as Small Grains Centre), Sensako (established in the mid-1960's, becoming independent in 1999 after functioning as part of Monsanto), and Pannar (entering the wheat breeding sector in the 1990's). As a result of this selective breeding the average yield for dry land wheat have increased from less than 0.5 tons/ha in 1936 to more than 3.5 ton/ha in 2015 [5]. This increase in wheat yield as well as an increase in quality can be attributed to research efforts from various disciplines such as plant breeding, agronomy, crop physiology and crop protection [6]. In the quest for yield and quality, however, some important traits might have

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been lost as a result of low yielding cultivars, with other good characteristics, being discarded. Instead, there has been extreme focus on a few accessions, which led to a loss of biodiversity leading to difficulties to meet future agricultural demands, because genetic variability to provide climatic and pest adaptation is lost [7]. There is also a decline in the nutrition of wheat, as a result of breeding efforts concentrating on higher yields rather than health benefits and taste. The cultivation of ancient wheat land races was widespread in the past, but they are today only grown on a small area in some countries for traditional foods. Because they have been proposed to be rich sources of bioactive components these ancient wheat landraces are believed to be suitable for producing high value food products with enhanced health benefits [8]. Ancient wheat landraces are usually grown in organically, or traditional low input, farming systems, while modern wheat cultivars are usually bred for high input intensive systems [1]. In developed countries, consumer preferences are moving towards high quality, regional products, utilising crops that are not intensively bred and produced on a large scale, but instead offer novel and interesting products and tastes [9]. In South Africa there has also been a renewed interest in older wheat forms. Mr. James Moffett, wheat farmer, cultivates historical wheat cultivars organically on his farm, Kirklington, at Clocolan in the Eastern Free State, South Africa [10]. The wheat is stone milled and delivered to an artisan bakery in Stellenbosch, Schoon de Companje, where speciality breads, with superior taste, are baked [10]. Mr. Moffett cultivates Khorasan wheat (*Triticum turanicum*), as well as a South African bread wheat cultivar, registered as Witwol. Other older wheat cultivars that have potential for a niche market are Bolane and Makaloate. These varieties are cultivated in Lesotho, a small land locked country in South Africa, bordered in the north-west by the Eastern Free State (a dry land wheat production area), north-east by KwaZulu-Natal and south by the Eastern Cape. Farmers in Lesotho still rely on recycled seed, do not use fertilisers and use ox drawn implements to prepare the seedbed. Selections for suitable wheat cultivars are made in the field in the area where the wheat cultivar is grown. Longin and Wűrschum [9] believe that a multi-disciplinary step-wise but holistic approach that takes both agronomic properties like disease tolerance and yield potential as well as nutritional and taste profiles into account is needed to select the best candidates to re-introduce to the market. To determine how these older landraces, compare to modern wheat cultivars, Witwol, Bolane and Makaloate were compared to dry land wheat cultivars, currently on the market in South Africa, with regard to Russian wheat aphid resistance, yield, hectolitre mass, protein content, dough mixing time and loaf volume.

Materials and Methods

Field trial

A field trial was planted at ARC-Small Grains, Bethlehem, South Africa (S28,5670°E28,29525°) (Figure 1), in a complete randomised block design. Seven dry land wheat cultivars on the market in South Africa, Elands, Senqu, Gariep, PAN3379, PAN3118 and SST387, two cultivars from the highlands of Lesotho, Bolane and Makaloate, and a South African 'heritage' cultivar, Witwol was planted in 5 m × 5 row blocks with four replications on 10 July 2016. The trial was evaluated for Russian wheat aphid damage on 1 November 2016. A five-point damage scale was used for Russian wheat aphid damage where: 1-No visible damage (Resistant); 2-Cloretic spots on leaves (Resistant); 3-Longitudinal white or purple striping on leaves (Susceptible); 4-Longitudinal rolling of leaves (Susceptible); 5-Plant dead (Susceptible). Each plot was analysed according to this scale. The trial was harvested on 10 January 2017.

Field trials at farm Kirklington, Clocolan

The cultivar Witwol, together with Khorasan and Highland Hard Red (HHR) (SST124 retained seed), was planted on the farm, Kirklington at Clocolan (S28,83697°E27,72223°) on 3 July 2015 by farmer, Mr. James Moffett. Wheat cultivars were planted at a plant density of 100 kg/ha with 400 kg/ha Talborne (6:3:4) Organic Fertiliser.

Quality analysis

The yield was determined for each plot and the seed for each plot was analysed for hectolitre mass (kg/hl), protein content (12% protein basis), dough mixing time (min) and loaf volume (12% protein basis) at the quality laboratory at ARC-Small Grains.

i. Hectolitre mass was determined by means of a two-level funnel according to AACC method 55-10 [11]. The obtained weight was divided by 5, and expressed as kg/hl.

ii. Protein content (AACC method 39-11.01, using a FOSS Grain Analyser 1241, with NIR-technology) was determined on the white flour samples [11].

iii. Mixograph analyses (AACC method 54-40 A) were performed to determine the dough development time (mixing time) of each cultivar [11].

iv. The optimised, straight-dough baking procedure (AACC method 10-10 B) was performed and loaf volume (as is) was determined by means of rapeseed displacement according to AACC method 10-05 [11]. Loaf volume expressed on a 12% protein basis (corrected loaf volume), was determined as follows: For each 1% of

Figure 1: Wheat trial at ARC-small grains (S28,15670°E28,29525°) during 2016: a) Bolane; b) Witwol; c) Makaloate.

Table 1: Comparison of resistance to Russian Wheat Aphid (RWA), yield (tons/ha), hectolitre mass (kg/hl), protein content, dough mixing time and loaf volume of different dry land wheat cultivars in South Africa.

Entry	RWA damage	Yield (tons/ha)	Hectolitre mass (kg/hl)	Protein content (12% protein basis)	Mixing time (min)	Loaf volume (12% protein basis)
Witwol	2.50abc	0.96e	76.51d	14.30a	2.10fg	876.10a
Bolane	3.25ab	2.16cd	76.75cd	10.22e	2.50ef	680.00d
Makaloate	3.50a	1.73d	75.65e	12.35bc	1.65g	857.50ab
Elands	0.00d	3.14ab	80.30a	12.17bcd	3.45ab	811.20abc
Senqu	2.25abc	3.58a	79.93a	13.30ab	3.18bcd	828.80abc
Gariep	1.00cd	2.61bc	79.75a	12.50bc	3.38abc	863.80ab
PAN 3379	0.75cd	2.35cd	78.78b	11.20cde	2.73de	781.20bc
PAN 3161	1.50bcd	3.61a	77.28c	10.65de	3.78a	761.20cd
PAN 3118	3.50a	2.25cd	75.45e	11.92bcd	2.88cde	816.20abc
SST 387	1.75abcd	3.12ab	75.63e	11.90bcd	3.10bcd	801.20abc
LSD	1.91	0.6415	0.6947	1.559	0.5053	90.34

a, b, c, d, e, f, and g: Means within a column followed by the same lowercase letter are not significantly different ($P < 0.0001$).

protein content above 12%, 40 cm^3 was subtracted from the measured loaf volume (as is) and for each 1% protein content below 12%, 40 cm^3 were added to the measured loaf volume (as is).

Statistical analysis

The data of each plot was determined separately, and cultivar groups were analysed using a two-way Analysis of Variance (ANOVA). Means with significant ($P < 0.05$) interactions were separated by Fisher's protected Least Significant Difference (LSD) test at the 5% level.

Results

At ARC-Small Grains, Bethlehem, soil moisture was acceptable at planting and good growth was achieved for all the cultivars planted. From October onward, there were significant infestations of Russian wheat aphid in the trial. Witwol and Bolane, both awnless cultivars, experienced significant bird damage in late November before harvest. This could have affected the yield of these cultivars significantly.

Field evaluation of Russian Wheat Aphid (RWA) damage

There are currently four RWA biotypes known in South Africa, RWASA1-RWASA4. The feeding of these RWA biotypes affect the wheat cultivars differently, depending on the resistance in the wheat cultivars [12]. The RWA biotypes RWASA3 and RWASA4 was present in the study area during the trials. PAN3118 is susceptible against all RWA biotypes, while Elands, Gariep, Senqu and SST387 have resistance against RWASA1 and PAN3379 and PAN3161 have resistance against all four RWA biotypes in South Africa. Analysis of the main effects of RWA damage rating on the wheat cultivars in the trial indicated significant variation in RWA damage for evaluated wheat cultivars, suggesting that there were differences in resistance response to RWA feeding by the wheat cultivars evaluated. The highest damage was observed on PAN3118 and Makaloate, with Witwol, Bolane and Senqu also having a significantly higher damage rating than the RWA resistant cultivars, PAN3379, PAN3161, Elands, Gariep and SST387 (Table 1).

Field trials at farm Kirklington, Clocolan

At Kirklington, Clocolan, soil moisture was acceptable at planting and excellent growth was achieved in the first three months from July to September. Growth from October to December was severely hampered by lack of rain (50 mm was recorded for the growing season) and Witwol, Khorasan and Highland Hard Red (HHR) were affected, however the Witwol and HHR were shorter, while Khorasan continued to grow. No small pests or diseases of significance were recorded. Witwol, with spikes without awns, is susceptible to birds (quella & guinea fowl) and animals (warthog), which is a drawback if not controlled. Witwol's yield was 1000 kg/ha, which is lower than the average yield of modern cultivars cultivated in the area, but expressed higher drought tolerance than other cultivars cultivated in the area.

Yield and quality evaluation

There were significant yield differences between the various cultivars, where PAN3161, Senqu, Elands and SST387 showed the highest yields (Table 1). Witwol produced a significantly lower yield compared to other cultivars (Table 1).

When cultivars are commercially released, they are compared to a wheat quality standard, Elands for the dry land Free State region. Deviations from the quality standard's obtained values are allowed for all the quality characteristics when comparing the cultivar. If not compared to a quality standard, generally a mixing time between 2.5 and 4.0 minutes and protein content above 11% being desirable. A hectolitre mass of 76 kg/hl is acceptable to industry. Elands, Senqu, and Gariep had

the highest hectolitre mass, while the hectolitre mass of Makaloate, PAN3118 and SST387 was below the acceptable level of 76 kg/hl (Table 1). Witwol had significantly higher protein content than all other cultivars, while Bolane and PAN3161 had a protein content below the acceptable level of 11% (Table 1). Gariep had the highest mixing time, while the mixing time of Witwol. Bolane and Makaloate was significantly lower than that of the other cultivars (Table 1). Witwol had the highest loaf volume, while Bolane had the lowest (Table 1). Although Makaloate had a higher loaf volume than Elands, its mixing time was too short. Bolane had an acceptable mixing time, but its loaf volume was too low compared to Elands, although the lower loaf volume could be due to the lower protein content of Bolane. Witwol also had an acceptable loaf volume, but the mixing time was also too short.

Discussion

Bolane (Figure 1a) is a tall cultivar, which was introduced to Lesotho in the 1960s [13]. The cultivar is used for bread making and its long straw is also suited for roofing of traditional houses. Bolane is a soft white wheat and farmers in Lesotho prefer it for its superior bread making qualities and it is widely cultivated in various parts of Mokhotlong and Thaba Tseka in the Lesotho highlands. This cultivar is believed to be well adapted to high altitudes. Witwol (Figure 1b) is a 'heritage' cultivar that was released in South Africa in 1905. This cultivar is planted by organic wheat farmers in the Eastern Free State and Northern Cape for a niche market in the Western Cape [10].

When wheat cultivars are cultivated in the field, environmental factors will have an impact on the final yield, hectolitre mass and protein content of the specific cultivar. Cultivars will have variable reactions to environmental pressures. These environmental pressures include drought stress, insect and disease damage. Russian wheat aphid is a common wheat pest. The cultivars in the present study responded differently to Russian wheat aphid infestation with the highest level of damage recorded on PAN3118, Makaloate and Bolane. This might affect the yield and quality of these cultivars.

A classical wheat production chain involves producers, millers, and bakers, but we should never forget that the consumer is also an important component in this chain. Wheat quality has different meanings to different people, depending on whose hands are handling the wheat from the field to the table. Producers want high yielding cultivars with acceptable hectolitre mass (> 76 kg/hl), protein content (> 11%) and falling number (> 250s), millers prefer cultivars with high flour yields and acceptable flour colour. Bakers want acceptable dough characteristics and high loaf volumes. Consumers rely on their senses - what they see, feel, smell and taste. Since the final test of a bread wheat cultivar must pass is producing an acceptable loaf of bread with good taste, by eliminating "values" and considering only appearance of these loaves, Witwol and Makaloate had both comparable loaf volumes and loaf characteristics to the quality standard, Elands (Figure 2).

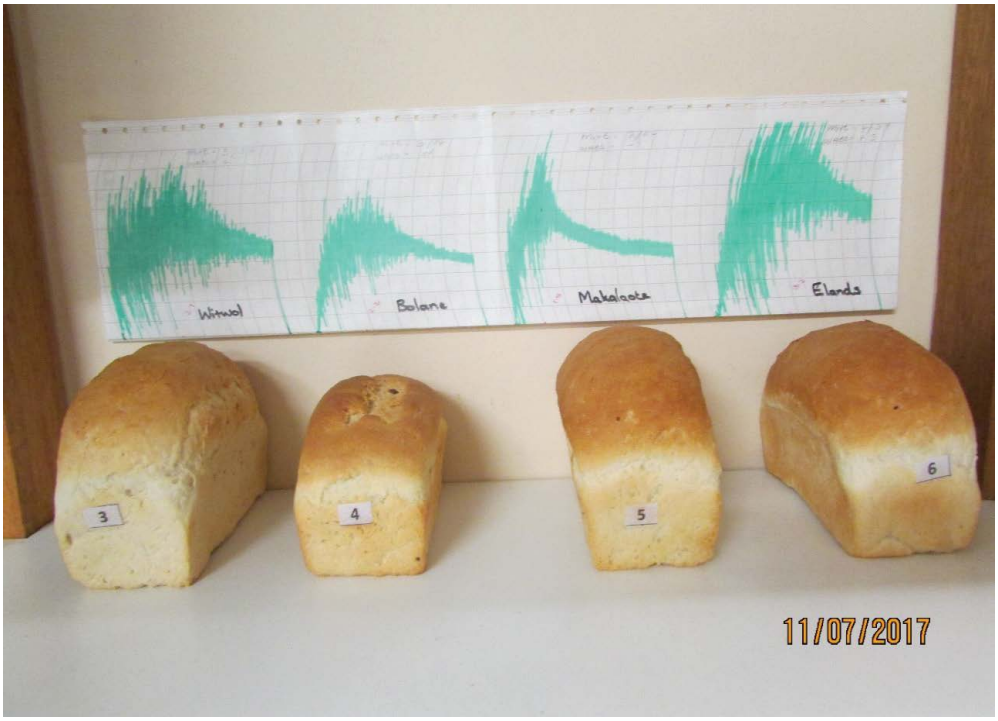

Figure 2: From left to right - Mixograms and a loaf of bread of Witwol, Bolane, Makaloate and Elands (the quality standard).

Large commercial wheat producers in South Africa face the problem of decreasing commodity prices and competition with cheaper low-quality imports. These farmers, as well as small-scale farmers would benefit from a crop that promise a better and more robust income, independent of the global market of major crops. Consumer demand for artisanal, 'unmodified' products that are healthy and superior in taste offers a promising avenue for the needs of producers, millers, and bakers for profitable niche products. Although the 'heritage' cultivar Witwol and the traditional Lesotho cultivars Bolane and Makaloate do not compete well with commercial wheat cultivars as far as yield is concerned, they show promise for a niche market for high quality products. Additionally, according to farmer, James Moffett, Witwol shows very good drought tolerance [10], while Bolane and Makaloate is adapted to mountainous areas where few other crops can be cultivated [14]. A stable and sustainable product chain must be established by co-operation between producers, millers and bakers. This can be achieved by cultivation contracts between the producer and the baker. According to James Moffett, organic farming can work on a system that depends on trust [10]. The farmer decides on the percentage premium price and the cash price is adapted according to the year's production cost and yield. In better years, the price can therefore be lower. It will also be practical to incorporate a wheat breeder into the product chain, since breeding would be an important component for the long-term success of the 'heritage' and traditional cultivars.

Conclusions

The re-introduction to the market and use of 'heritage' and traditional wheat cultivars might be crucial for the improvement of genetic diversity in crop breeding. Longin and Wűrschum [9] proposed the holistic and sustainable use of available ancient wheat cultivars by re-introducing them as crops and creating markets for specialty products. Since these 'heritage' and traditional wheat cultivars are low yielding compared to modern wheat cultivars currently on the market and not adapted to modern agricultural practices and pest and disease pressures, they will not contribute significantly to feeding the growing world population. These cultivars do however have a place in markets where its holistic use as crop is a viable option for producers, millers and bakers who cater for specific consumer preferences. Encouraging the cultivation of these cultivars will increase the diversity of bread products as far as quality and taste is concerned.

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