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# GRAIN YIELD AND QUALITY COMPONENTS OF PURE AND MIXED CROPPING OF BREAD WHEAT (*TRITICUM AESTIVUM* L.) AND TRITICALE (X*TRITICOSECALE* WITTMACK)

**RUKIYE KARA [1], ZIYA DUMLUPINAR[2*], TEVRICAN DOKUYUCU[2], AYDIN AKKAYA[2] AND MEVLUT AKCURA[3]**

[1]*Kahramanmaras Agricultural Research Institute, K.Maras, Turkey*
[2]*KSU, Agricultural Faculty, Field Crops Dep. 46060, K.Maras, Turkey*
[3]*Bingol University, Agricultural Faculty, Field Crops Dep. Bingol, Turkey.*
*E–mail: zdumlupinar@ksu.edu.tr*

**Abstract**

This research was carried out to determine the advantages of mixed cropping of bread wheat (BW) and triticale (T) compared to pure cropping, during three cropping years, under the East Mediterranean Region of Turkey. Bread wheat and triticale mixtures were arranged in a ratio as 100:0, 80:20, 60:40, 40:60, 20:80 and 0:100. Sowing rates were 550 seed $m^{-2}$ for all plots.

According to the results, grain weight per head (GW $H^{-1}$), grain number per head (GN $H^{-1}$), ratio of grains in mixed cropping (RGMC) of BW, protein ration (PR) and dry gluten (DG) amount of products were significantly decreased by increasing of T plants in the mixed cropping plots, compared to pure cropping of BW. Triticale was the highest yielding (9250 kg $ha^{-1}$) component of mixed cropping. Contributions of triticale plants were also significant for grain yield of mixtures. In addition, relative yield total (RYT) and indices of inter-specific competition (Rbwt and Rtbw) indicated that, mixed cropping of BW and T did not have any advantages for GY over the pure cropping of triticale.

The year x mixed cropping interaction was only significant for GN $H^{-1}$.

## Introduction

The hexaploid triticale (×*Triticosecale* Wittmack) (AABBRR) created by crossing species of wheat (*Triticum*) (AABB) and rye (*Secale*) (RR) combines the features of both parental cereals. Triticale has high yield potential and grain quality of wheat and the resistance to pathogens of rye (Tohver *et al*., 2005).

Triticale production is gradually increasing in agriculture due to spreading of new improved cultivars. Triticale is also used in bakery industry (Lorenz & Welsh, 1976, 1977) and it has high protein content (average 14-15%) (Täht *et al*., 1998). There are a number of researches indicate that triticale and bread wheat cultivars may be used for flour production by mixing at different rates (Leitao *et al*., 1981; Jardine & Pape, 1983; Heger & Eggum, 1991).

However, there is limited information related with mixed cropping of different-cereals, especially spring bread wheat sown in fall and triticale plants in the Mediterranean region. It was reported that performance of components was related with their yielding ability in monocultures (Blijenberg & Sneep, 1975). Fejer *et al*., (1982) reported that there was not any yield advantage of barley-oat mixtures over higher yielding mono-crop. Pyke & Hedley (1985) determined morphological differences affected the performance of cultivars in monocultures and crop mixtures. Jokinen (1991) reported that barley-oats mixtures had over yield than monocultures. However, protein yield of mixtures did not differ from the yield of the highest yielding component grown alone. Mergoum *et al*., (1998) reported that for triticale mixtures, the highest yielding line of triticale was the best for mixing ability or contribution to grain yield of the mixtures. Woldeamlak (2001) pointed out mixed cropping of barley and wheat increased grain yield @ 57% over the sole crops, wheat plants were first suppressed by barley but later on grew taller than barley, and mixed cropping was significantly more stable than barley and wheat sole cropping. There are different results about the yield advantages of mixed cropping of small grains cereal plants. Spring bread wheat cultivars and newly registered triticale (Tacettinbey) are commonly sown in fall at the Mediterranean coastal areas of Turkey and Tacettinbey cv. is gradually spreading. However, there is no available research to compare performance of the cultivars in the mixed cropping under the Mediterranean coastal cereal production lands of Turkey. Therefore, this research was conducted i) to study inter-specific competition between bread wheat (Bal-Atilla cv.) and triticale (Tacettinbey cv.) according to grain yield and quality of the product, ii) to determine optimum wheat-triticale ratio in respect to grain yield and quality of the product in the consecutive three years.

## Materials and Methods

Field trials were carried out consecutively for three years (1999 to 2002) at Kahramanmaras province (East–Mediterranean Region of Turkey) located between 37° 53' N, 36° 58' E. Climate of the region is typical of Mediterranean climate (Table 1). Some chemical and physical traits of experiment soils sampled from 0-30 cm topsoil are shown in Table 2.

Bread wheat (*Triticum aestivum* L.) cultivar (Bal-Atilla) and Triticale (x*Triticosecale* Wittmack) cultivar (Tacettinbey) were used as plant materials, sowing dates were on 20 November 1999, 8 November 2000 and 17 November 2001. The experiments were arranged in a randomized complete block design with four replications. Pure cropping of components and all combination of replacement series of bread wheat (BW) and triticale (T) (100:0, 80:20, 60:40, 40:60, 20:80 and 0:100) were randomly located in blocks, at the same sowing rate (550 seed $m^{-2}$), to compare each species which were also grown in pure cropping at the same rate as their presence in the mixed stand (Bi & Turvey, 1994; Fetene, 2003).

Plot sizes were arranged as 6x1.2m and each plot was eight rows. The BW and T seeds were mixed and then planted by plot-drill. Fertilizers were applied as 80 kg $ha^{-1}$ N and 80 kg $ha^{-1}$ $P_2O_5$ at planting. In addition, topdressing was applied as 100 kg $ha^{-1}$ N at tillering. Herbicide (Tribenuron–Methyl 75%) was used for weed control. In the first two years, experiments were irrigated at anthesis, until field capacity, due to lower rainfall. In the third year, experiment was carried out in rainfed conditions due to higher available rainfall than average rainfall for long-term (Table 1).

In the experiment, 1000 grain-weight (1000-GW), grain number per head (GN $H^{-1}$), grain weight per head (GW $H^{-1}$), ratio of grains in mixed cropping (RGMC) and grain yield (GY) were measured as described by, Williams *et al*., (1988), Abdel–Gani *et al*., (1999) and Fetene (2003). In addition, protein ratio (PR) (Kjeldahl method, Mousia *et al*., 2004), particle size index (PSI) (SKCS model 4100, Perten Instruments, 1995) and dry gluten (DG) (Kieffer *et al*., 1998) were measured.

Semere & Froud–Williams (2001) reported effectiveness of mixed cropping were measured by using the land equivalent ratio (LER) which was based on the relative land requirement for mixed cropping compared with monocultures, and relative yield total (RYT) was also identical to LER. Therefore, two indices were used in this experiment; ($_i$) the relative yield total (RYT), ($_{ii}$) indices of inter–specific competition ($R_{ji}$) (Jolliffe, 2000; Fetene, 2003).

**Table 4. GY, PR, DG and PSI values of BW and T in mixed cropping and pure cropping over three years.**

| Replacement series | GY (kg ha$^{-1}$) | PR (%) | DG (%) | PSI |
|---|---|---|---|---|
| | ** | ** | * | * |
| Bread wheat pure cropping | 7320 c# | 12.44 a# | 10.64 a# | 51.10 c# |
| 80:20 | 7040 c | 11.98 ab | 10.52 ab | 54.44 abc |
| 60:40 | 7640 bc | 11.62 b | 9.61 bc | 52.56 bc |
| 40:60 | 7690 bc | 10.97 c | 8.99 c | 54.08 abc |
| 20:80 | 8540 ab | 10.93 c | 9.02 c | 55.67 ab |
| Triticale pure cropping | 9250 a | 10.84 c | 8.84 c | 57.56 a |
| CV (%) | 10.94 | 4.22 | 8.38 | 6.92 |
| LSD | 950.08 | 0.561 | 0.953 | 4.447 |

** Significant at 1% level, * Significant at 5% level.

# The values with the same letters were not significantly different.

The relative yield total (RYT), measure of resource complementary, was calculated using the equation, RYT = $Y_{ij}$ / $Y_{ii}$+ $Y_{ji}$ / $Y_{jj}$ (Fetene, 2003). Where $Y_{ii}$ and $Y_{jj}$ were the yields of pure cropping of each species, $Y_{ij}$ was the yield of species $_i$ in mixture with species $_j$ and $Y_{ji}$ was the yield of species $_j$ in mixtures with $_i$. In two species mixtures, RYT values close to 1.00 indicate that two species have equal demands on the same limiting resources. RYT values greater than 1.00 indicate that species that still compete for the some resources might also make demands on different resources. RYT values less than 1.00 indicate that mutual antagonism (Bi & Turvey, 1994; Fetene, 2003).

Inter-specific competition ($R_{ji}$) between BW and T was assessed following $R_{ji}$ = ($Y_{ii}$ - $Y_{ij}$) / $Y_{ii}$ (Fetene, 2003). Where $R_{ji}$ is the relative effect of inter–specific competition from species $_j$ on the yield of species $_i$. $Y_{ii}$ is the yield of species $_i$ in its pure cropping. $Y_{ij}$ is the yield of species $_i$ in mixture with species $_j$ (Fetene, 2003).

Protein ratio and PSI were evaluated according to the scales reported by Williams *et al.*, (1988). According to this scale; protein ratio; < 9% = very low, 9-11.5% = low, 11.6-13.5% = medium, 13.6-15.5% = high, 15.6-17.5% = very high, 17.5% < extra high, PSI; < 28 = extra hard, 29-39 = very hard, 40-48 = hard, 49-56 = medium hard, 57-64 = medium soft, 65-72 = soft, 73-78 = very soft, 78 < extra soft.

Data was analyzed over the results of three years by statistical software of SAS (SAS Institute. 1999. SAS System for Windows Release 8.01. SAS Inst., Cary, NC.) and LSD tests were used for ranking of means. RYT and $R_{ji}$ were evaluated graphically in replacement diagrams (Harper, 1977; Bi & Turvey, 1994).

## Results and Discussion

A measure of 1000-GW, GW $H^{-1}$, GN $H^{-1}$ and RGMC values in the replacement series of mixed and pure cropping are given as an average of three years, in Table 3 while, GY, PR, DG and PSI values are given in Table 4.

These results indicate 1000-GW of both cultivars in replacement series of mixed cropping and in pure cropping was not significantly different.

Grain weight and grain number per head in mixed cropping for BW significantly and gradually decreased. The values were low in pure cropping compared to 80:20 by increasing of triticale plants in mixtures (Table 3). Values for GW $H^{-1}$ and GN $H^{-1}$ were the highest in pure cropping of BW and in mixed cropping 80:20 (GW $H^{-1}$ and GN $H^{-1}$, 1.55 and 33.9 g, respectively) and they were the lowest in mixed cropping 20:80 (1.20 and 18.27 g). However, GW $H^{-1}$ and GN $H^{-1}$ values of triticale cv. Tacettinbey were not significantly changed in mixtures compared to pure cropping.

GW $H^{-1}$ and GN $H^{-1}$ values of BW were significantly reduced by decreasing of BW plants or increasing of triticale plants in mixed cropping compared to pure cropping of BW. RGMC value of triticale was significantly reduced by decreasing numbers of T plants in mixed cropping. RGMC value of triticale was the lowest in mixed cropping 80:20. However, ratio of triticale grains in mixed cropping at harvest were higher than the ratio of triticale grains in mixed cropping at planting. Ratio of triticale grains increased to 42, 62, 77 and 84% in replacement series, 80:20, 60:40, 40:60 and 20:80 respectively.

Grain yield was significantly increased by mixed cropping compared to pure cropping of BW, especially due to increasing numbers of triticale plants in replacement series 60:40 (7640 kg $ha^{-1}$), 40:60 (7690 kg $ha^{-1}$) and 20:80 (8540 kg $ha^{-1}$). However, there was no yield advantage of mixed cropping over higher yielding pure cropping of triticale (9250 kg $ha^{-1}$).

Protein ratios were significantly changed in the mixtures. There were significant and gradually decreasing for PR in the mixtures compared to pure cropping of BW cultivar Bal–Atilla's PR. However, in the replacement series (80:20) this decreasing for PR was not significant. There were no PR advantages of BW-Triticale mixtures over pure cropping of BW, which supplied the highest PR (12.44%).

Dry gluten amount of product obtained from mixed cropping 80:20 was not significantly different from those obtained from pure cropping of BW. DG of product 80:20 (10.52%) was slightly lower than product obtained from pure cropping of BW (10.64%). However, DG was significantly lower in other replacement series of BW and T, compared to pure cropping of BW. However, DG in mixed cropping was significantly increased in replacement series 60:40 (9.61%) and 80:20 (10.52%), compared to pure cropping of triticale (8.84%). In mixed cropping, DG significantly increased by increasing numbers of BW plants. Nevertheless, increasing of triticale grains at the rate of 20-42% in mixed cropping had not significant effect on decreasing of DG values.

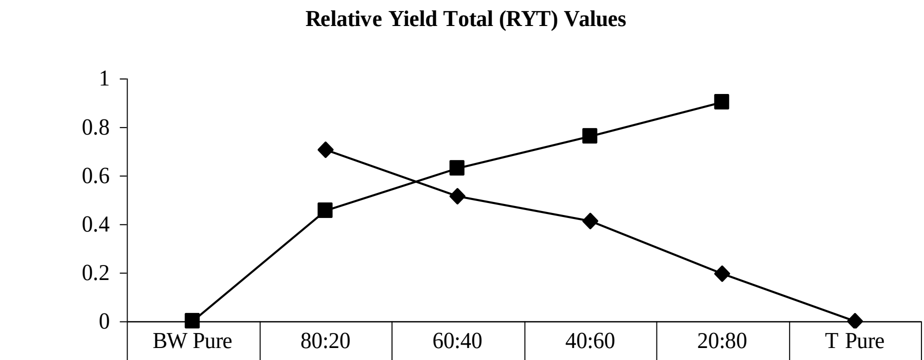
Particle size index was significantly decreased in replacement series 60:40 (52.56%) compared to pure cropping of triticale (57.56%). PSI of product obtained from mixed cropping 80:20 (54.44%) was not significantly different from those obtained from pure cropping of BW (51.10%). Williams *et al*., (1988) reported that, all replacement series were 49–56 = medium hard, except triticale pure cropping, 57-64 = medium soft. Thus there were no PSI advantages of mixed cropping over the pure cropping of triticale.

The relative effects of inter-specific competition, from BW on T (Rbwt) and from T on BW (Rtbw) for GY and relative yield contribution of component crops are shown in Fig. 1. It is possible to see relative contribution effect of triticale on total yield (Fig. 1).

The relative yield total values for replacement series were determined as close to 1 for GY (Fig. 1). RYT values equal or close to 1 in mixed cropping of two species, indicate that both species made equal demands on the same limiting resources.

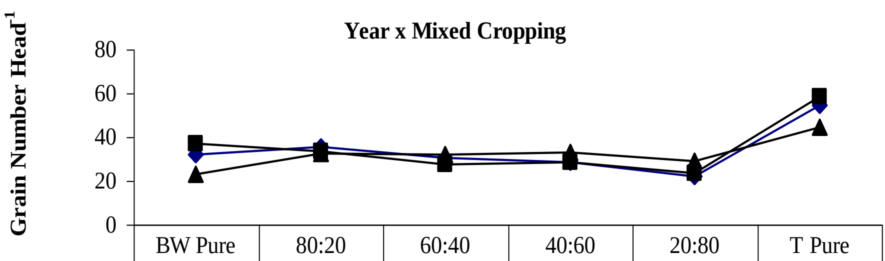
Inter-specific competition of BW on T (Rbwt, 0.706) was higher than inter-specific competition of triticale on BW (Rtbw, 0.456) in mixed cropping 80:20. However, inter–specific competition of T on BW (Rtbw) was higher than inter–specific competition of BW on T (Rbwt) in mixed cropping 60:40, 40:60 and 20:80 (Fig. 1).

The year x mixed cropping interaction was significantly important for GN $H^{-1}$ (Fig. 2). Pure cropping of T had the highest values for GN $H^{-1}$ in the all three years ($1^{st}$, $2^{nd}$ and $3^{rd}$ years, 54.52, 58.60 and 44.55 respectively) comparing to pure cropping of BW and all replacement series in the all replacement series, GN $H^{-1}$ was higher, compared to pure cropping of BW in 2001-02 cropping year. However, GN $H^{-1}$ for pure cropping of BW and T were higher than the all replacement series in 2000-01. This situation was same for GN $H^{-1}$ in 1999-00 cropping year, except 80:20 mixed cropping. This situation was due to different plant growing and climatic conditions among the years.




| | BW Pure | 80:20 | 60:40 | 40:60 | 20:80 | T Pure |
|---|---|---|---|---|---|---|
| Rbwt | | 0.706 | 0.516 | 0.413 | 0.197 | 0 |
| Rtbw | 0 | 0.454 | 0.628 | 0.761 | 0.901 | |

Fig. 1 The Relative Yield Total (RYT) values of mixed cropping and inter-specific competition from BW on T (Rbwt) and from T on BW (Rtbw) for GY.




| | BW Pure | 80:20 | 60:40 | 40:60 | 20:80 | T Pure |
|---|---|---|---|---|---|---|
| 1999-00 | 31.95 | 35.32 | 30.42 | 28.45 | 21.92 | 54.52 |
| 2000-01 | 36.95 | 33.5 | 27.52 | 28.35 | 23.52 | 58.6 |
| 2001-02 | 22.77 | 32.75 | 31.95 | 33.15 | 29.17 | 44.55 |

Fig. 2 Interaction between Year and Mixed Cropping for GN $H^{-1}$.

There were no advantages of mixtures over pure cropping for GW $H^{-1}$ and GN $H^{-1}$. These results might be due to lower competition ability of Bal-Atilla cv. of BW in comparison to Tacettinbey cv. of T, as for nutrient use and light interception. Willey & Holliday (1971) reported that decreasing of assimilate accumulation, spikelet numbers, GW $H^{-1}$, GN $H^{-1}$ and 1000-GW in the lower light conditions. This situation might be due to higher negative response of BW cultivar Bal-Atilla to mixed cropping and its lower competition ability.

Ratio of grains in mixed cropping for BW was significantly decreased by decreasing of BW plants or increasing of triticale plants in mixed cropping compared to pure cropping of BW. This situation may be due to higher negative response of BW cv. Bal-Atilla to mixed cropping and its lower competition ability. Schlenhuber & Curtis (1961) and Villarreal (1980) indicated differences at planting and harvesting of mixed cropping. This was proof for higher competition ability of triticale cv. Tacettinbey in mixed cropping.

There are different results related with grain yield of cereals crops grown in mixture cropping in literature. Jokinen (1991) reported that, barley-oat mixtures had more yield than monocultures. Woldeamlak (2001) pointed out that, barley and wheat mixtures increased GY over the sole crops. However, Fejer *et al*., (1982) indicated that, there was no yield advantage of barley-oat mixtures over higher yielding mono crop. In addition, relative contribution of triticale to the GY of mixture was more than the contribution of BW, and triticale had higher mixing ability in the mixtures in this study. Mergoum *et al*., (1998) also reported that, for triticale mixtures the highest yielding line of triticale was the best for mixing ability or contribution to GY of the mixtures in their research.

According to the scales reported by Williams *et al*., (1988), PR of pure cropping of BW and 80:20 of mixtures were medium, pure cropping of T and the other mixtures were low. In literature there were no advantages for PR obtained from mixtures (Jokinen, 1991). These results were also similar with our results.

Mixed cropping of these two species did not have any yield advantages over the pure cropping of species. Previous authors also used RYT values to determine advantages of mixed cropping for the other species (Bi & Turvey, 1994; Juskiw *et al*., 2000; Fetene, 2003).

In general, the relative effect of inter-specific competition of T on BW was greater than that of BW towards T. This situation showed competition ability of Tacettinbey cv. of T was higher than competition ability of Bal-Atilla cv. of BW in all replacement series, except mixed cropping 80:20 in which BW population was the highest. Previous authors also determined inter-specific competition of components by index of inter-specific competition (Jolliffe, 2000; Fetene, 2003). Inter-specific competition and RYT were the most important criteria in mixed cropping (Wahua & Miller, 1978; Braakhekke, 1980; Bi & Turvey, 1994; Fetene, 2003). It was reported that competition ability of species was significantly related with morphological traits, and competition was lower between the species, with different morphological traits (Weaver & Clements, 1986).

Results indicate that, Bal-Atilla cv. of BW had negatively higher response to mixed cropping than Tacettinbey cv. of triticale, and competition ability of Bal-Atilla cv. of BW was lower than Tacettinbey cv. of triticale. Indices (Rtbw) of inter–specific competition of these species were also proof for higher competition ability of triticale. According to the RYT values, there were no yield advantages of mixed cropping of Bal-Atilla cv. of BW and Tacettinbey cv. of T over higher yielding pure cropping of triticale.

However, ratio of triticale grains in mixed cropping at harvest was higher than those at planting. Triticale rates at harvest were 42, 62, 77 and 84% respectively, while those rates at planting were 20, 40, 60, and 80%, respectively. Although, increasing of triticale grains to 42% in mixed cropping 80:20, PR, DG and PSI values in mixed cropping 80:20 were not significantly different from that of BW pure cropping. Therefore, it may be useful in practical using of mixed products of 80:20.

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