THE EFFECT OF SEED SPROUTING DAMAGE ON FIELD EMERGENCE AND YIELD OF SPRING TRITICALE*

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Manuscript received: June 11, 2004; Reviewed: October 13, 2004; Accepted for publication: December 19, 2004

ABSTRACT

In the years 1999-2001 two-factor field experiments were carried out in which the effects of spring triticale seed sprouting damage on field emergence, elements of the structure of yield and the yield were investigated. The research covered three cultivars: Gabo, Migo and Wanad. The statistical analysis of the results showed significant effects of years and sprouting damage on field emergence in all the years. Consequently, these factors affected the number of spikes per unit area, weight of 1,000 seeds and the yield in the years which were unfavourable for emergence (1999, 2000). In those years the decrease in yield, in the case of seeds with the most severe sprouting damage, ranged from 29% to 65% as compared with the control. In the favourable year 2001, in spite of a significant effect of seed sprouting damage on field emergence, the emergence level was so high that no decrease in the investigated elements of the structure of yield and the yield was observed.

KEY WORDS: field emergence, Maguire's coefficient, sprouting damage, spring triticale, yield

*The research work financed by the Committee for Scientific Research, the research project No. 5P06B 041 15

DETAILED ABSTRACT

The objective of the research was to determine whether seeds with various degrees of sprouting damage can be used as sowable material. The emergence dynamics and its effect on selected elements of the structure of yield and the yield itself were investigated. The seeds of three spring triticale cultivars (Gabo, Migo and Wanad), from three harvest years (1998-2000) were used. Directly after harvest they were induced to sprout under laboratory conditions, which made it possible to distinguish four degrees of sprouting damage. Field experiments also included control seeds, not induced to sprout. In the years 1999-2001 two-factor, split-splot field experiments, using a randomized block design, in three replications, were carried out. The investigated factors were the degrees of seed sprouting damage and the cultivars of spring triticale. The evaluation of the emergence was made every 2-3 days till the 21st day after sowing. These observations made it possible to calculate, using Maguire's coefficient, the emergence rate. The selected elements of the structure of yield and the yield were determined directly after harvest. The statistical analysis of the results showed significant effects of years and sprouting damage on field emergence in all the years (Table 1). In 1999 the influence of the most severe sprouting damage (the degrees 3 and 4) on field emergence was found starting with the 16th day after sowing and persisted till the 21st day (Fig. 1). In the year 2000 a significant effect of all the degrees of seed sprouting damage on emergence was found. In 2001 the highest level of field emergence – 80% - was noted for control seeds and those with light sprouting damage (the degrees 1 and 2). For the most sprouted seeds (the degrees 3 and 4) the emergence level estimated on successive observation dates was significantly lower. Similar results were obtained by Elias and Copeland [4], Chastain et al. [2], Barnard and Purchase [1], who observed a decrease in germination and field emergence of sprouted winter wheat seeds, proportional to the degree of sprouting damage. In 1999 and 2001 similar dynamics of emergence was reflected in the emergence rate. In those years the highest values of Maguire's coefficient were observed for the emergence of control seeds and those with the 1st and 2nd degree of sprouting damage (Fig. 2). In the year 2000 field emergence was the lowest and the significant effects of all the degrees of sprouting damage on a decrease in the emergence rate, as compared with the control, was found. These results correspond with the observation results for wheat and barley [6] and for winter triticale [11] which show that seeds with lower vigour are characterized by longer germination time. Seed sprouting damage affected considerably all the investigated traits except for the weight of seeds per spike (Table 2). For all the investigated traits significant interaction between the seasonal variability and the degrees of sprouting damage was found.

The yield, being the result of interaction of many factors, in two successive years (1999 and 2000) was significantly lower in plants which developed from most sprouted seeds (the degrees 3 and 4), as compared with the control. In successive years of the research it was found that the number of spikes per unit area decreased as the degree of sprouting damage increased (Fig. 3). In the years 1999 and 2000 that decrease ranged from 24% to 40% in plants which developed from most sprouted seeds (the degrees 3 and 4). In those years the decrease in yield, in the case of seeds with the most severe sprouting damage, ranged from 29% to 65% as compared with the control. Similar results were also obtained by Barnard and Purchase [1] and Elias and Copeland [4].

INTRODUCTION

Triticale is characterized by low resistance to sprouting ([8], [10], [15], [3]). Unfortunately the progress in breeding for resistance to sprouting is still highly unsatisfactory ([9], [16]). In consequence of seed sprouting germinability [12] and vigour become reduced, which directly affects the uniformity and level of field emergence [11], and the yield [14]. In the case of spring triticale, in which the time between harvest and sowing is several months, germinability and vigour seem to have greater influence on the reduction in field emergence and yield as compared with winter cultivars. That effect is modified by soil and weather conditions during the vegetation season [7].

The objective of the research was to determine whether seeds with various degrees of sprouting damage can be used as sowable material. The emergence dynamics and its effect on selected elements of the structure of yield and the yield itself were investigated.

MATERIAL AND METHODS

The seeds of three spring triticale cultivars (Gabo, Migo and Wanad), from three harvest years (1998-2000) were used. Directly after harvest they were induced to sprout under laboratory conditions, which made it possible to distinguish four degrees of sprouting damage: 1 - seeds with the testa broken near the embryo, 2 - seeds with visible primordia of a shoot and an embryonal root, 3 - seeds which developed one root, 4 - seeds which developed one shoot and three roots. Field experiments also included control seeds (K), not induced to sprout.

In the years 1999-2001 two-factor, split-splot field experiments, using a randomized block design, in three replications, were carried out at the Experimental Station in Prusy near Cracow. The investigated factors were the degrees of seed sprouting damage and the cultivars of spring triticale: Gabo, Migo and Wanad. The seeds were sown onto 0.9 m^2 plots in three rows 1.5 m wide, spaced 0.2 m apart, with 50 seeds in each row.

Depending on weather conditions the observations of the dynamics of field emergence were started between the 7th and the 14th day from the sowing. The evaluation of the emergence was made every 2-3 days till the 21st day after sowing. These observations made it possible to calculate, using Maguire's coefficient, the emergence rate. The selected elements of the structure of yield, i.e. the number of spikes. weight of seeds per spike. weight of 1,000 seeds and the yield were determined directly after harvest, which was done at the stage of full maturity. The number of spikes and the yield were recalculated for the area of 1 m^2.

For the investigated traits three-factor split-splot variance analyses were made, in which the investigated factors were years, degrees of sprouting damage and cultivars. For the distinguished sources of variability variance components were estimated using the mixed model, in which the degrees of sprouting damage and cultivars were accepted as constant factors and years as a random factor. To compare the mean values the Dunnett's t-test was used.

RESULTS AND DISCUSSION

1. Field emergence

The term of sowing depended on weather conditions and in successive years it was: March 31, 1999, April 13, 2000 and April 4, 2001. Weather conditions also affected the differentiation of emergence dynamics, the observations of which ended on the 21st day after sowing. In 1999 at the time of emergence rainfall total was 12.2 mm, and temperature total was 196.2 °C. The following year heavy rainfall delayed the sowing; however at the time of emergence rainfall was low (6.8 mm) with high temperature total (291.9 °C). In 2001 the emergence was accompanied by heavy rainfall (137.2 mm) and low temperatures (138.5°C). The analyses of variance, made separately for individual observation dates, and then the estimated components of variance showed that the greatest influence, ranging from 36% to 47%, was exerted by years (Table 1) and resulted from variable weather conditions at the time of emergence. The effect of sprouting damage was also significant, ranging from 19% to 51%. The tested cultivars had no effect on field emergence so when discussing the results mean values for cultivars were accepted. In all the years and on all the observation dates the weakest emergence was found for most sprouted seeds. Weather conditions modified the dynamics and level of emergence. Similar results were obtained by Elias and Copeland [4], Chastain et al. [2], Barnard and Purchase [1], who observed a decrease in germination and field emergence of sprouted winter wheat seeds, proportional to the degree of sprouting damage.

In the year 2000 observation of emergence could be made already on the 7th day after sowing (Fig. 1). On that date a significant effect of all the degrees of seed sprouting damage on emergence was found, which persisted till the last observation date. The specific weather conditions resulted in high dynamics of emergence observed till the 14th day after sowing, which for control seeds increased to 59% and remained at more or less that level till the end of the observations. The emergence of sprouted seeds was significantly lower as compared with the control and decreased, as the sprouting damage increased, from 40% to 10%. In the years 1999 and 2001 the observations of field emergence began not sooner than on the 14th day after sowing. In 1999 the influence of the most severe sprouting damage (the degrees 3 and 4) on field emergence was found starting with the 16th day after sowing and persisted till the 21st day. That year, on the last observation date the emergence of control seeds and those with the first degree of sprouting damage exceeded 70%. The emergence of the most sprouted seeds (the degrees 3 and 4) was significantly lower and ranged from 30% to 40%. In 2001 a significant differentiation of emergence was found already on the 14th day after sowing. That year the highest level of field emergence – 80% – was noted for control seeds and those with light sprouting damage (the degrees 1 and 2). For the most sprouted seeds (the degrees 3 and 4) the emergence level estimated on successive observation dates was significantly lower, on the 21st day acquiring the values above 60% and 40% respectively.

1. Emergence rate

The rate of field emergence, determined on the basis of Maguire's coefficient, depended on the dynamics of emergence, i.e. the results of the observations made between the 14th day and the 21st day after sowing and the final emergence percentage determined on the 21st day. The analysis of variance showed significant effects of years and seed sprouting damage on the emergence rate, and significant interaction of the investigated factors. The percentage of these sources in total variability was highest for years (38%) and degrees of seed sprouting damage (49%). No significant effect of cultivars on germination rate was found. In 1999 and 2001 similar dynamics of emergence was reflected in the emergence rate. In those years the highest values of Maguire's coefficient (Fig. 2) were observed for the emergence of control seeds and those with the 1st and 2nd degree of sprouting damage. More sprouted seeds (the degrees 3 and 4) were characterized by lower emergence rate, which resulted from slower dynamics and weaker emergence on successive observation dates. The rate of emergence observed in the year 2000 was different from the values of Maguire's coefficient obtained in 1999 and 2001. That year field emergence was the lowest and the dynamics of emergence between the 14th day and the 21st day after sowing was very poor for all the groups of the investigated seeds. That year significant effects of all the degrees of sprouting damage on a decrease in the emergence rate, as compared with the control, was found. These results correspond with the observation results for wheat and barley [6] and for winter triticale [11] which show that seeds with lower vigour are characterized by longer germination time.

2. Elements of the structure of yield and the yield

The differentiation of yield over years affected the variation of the elements of the yield structure and, in consequence, it influenced the yield of both the control seeds and sprouted seeds. The level of emergence was first reflected in the number of plants per unit area and then in the number of spikes. The analyses of variance made for the investigated traits and then the estimated components of variance showed that the greatest influence on the weight of seeds per spike and the yield per m^2, which amounted to 44.2% and 22.9% of the total variance respectively, was exerted by years. Seed sprouting damage affected considerably all the investigated traits except for the weight of seeds per spike (Table 2). For all the investigated traits significant interaction between the seasonal variability and the degrees of sprouting damage was found. The investigated cultivars differed in respect of the majority of traits, but their percentage in the total variability was very low so, as in the discussion of field emergence, mean values for the three cultivars were considered. The strong influence of years and sprouting damage degrees on field emergence produced significant differences in the number of spikes per m^2. According to Rozbicki [13] the yield of winter triticale seeds depends first of all on the number of spikes per unit area, then on the number of seeds per spike, and lastly on the weight of 1,000 seeds. In the experiments presented here the seeds with different sprouting damage were sown on separate plots. Single-seed sowing and wide interrow spacing were used, which made it possible to lessen the competitiveness of plants.

In successive years of the research it was found that the number of spikes per unit area decreased as the degree of sprouting damage increased (Fig. 3). In the years 1999 and 2000 that decrease ranged from 24% to 40% in plants which developed from most sprouted seeds (the degrees 3 and 4). In the last year of the research when field emergence acquired the highest values no significant effect of seed sprouting damage on the density of spikes was found, but a similar downward tendency was observed. If sowable material contains sprouted seeds with decreased vigour, the number of plants per unit area can be decreased. However in cereals a compensation phenomenon is observed [3], i.e. in the case of poor emergence the plants develop more spikes. It can be supposed that in the case of small percentage of sprouted seeds in the sowable material, as well as favourable temperature and appropriate soil moisture at the time of emergence, the negative effect on the yield will not be produced. Elias and Copeland [4], in the experiment with wheat, found lower density of spikes in plants developed from sprouted seeds. Haastrup Pedersen et al. [6] investigating winter wheat plants developed from seeds with low vigour found that the number of spikes in them was lower by 30% as compared with the control. In successive years of the research the weight of 1,000 seeds and the yield per unit area showed a tendency similar to that of the number of spikes.

Considering the investigated traits, the yield of seeds per spike showed a different tendency. In 1999 and 2001 no effect of seed sprouting damage on that trait was found. Only in the year 2000 when the weight of seeds per spike acquired the highest values a significant effect of seed sprouting damage on its decrease, as compared with the control, in plants which developed from the most sprouted seeds (the degrees 3 and 4) was noted.

The yield, being the result of interaction of many factors, in two successive years (1999 and 2000) was significantly lower in plants which developed from most sprouted seeds (the degrees 3 and 4), as compared with the control. In those years the reduction in the yield ranged from 29% to 65%. Similar results were obtained for winter cultivars; in unfavourable years the reduction in yield ranged from 28% to 54% [12]. A decrease in the yield of winter wheat seeds, correlated with an increase in the severity of seed sprouting damage, was also found by Barnard and Purchase [1] and Elias and Copeland [4], who distinguished similar degrees of sprouting damage. On the other hand, Foster et al. [5] reported that if wheat seeds were sown in the year of harvest, sprouting damage did not significantly affect the yield. In the presented research, in the year 2001 no significant effect of sprouting damage on a decrease in yield was found either. Chastain et al. [3] also did not observe differences in yield between plants developed from control seeds and sprouted seeds, except for those in which the embryo was damaged.

Table 1. Percentage of variance components and significance of the sources of variation for spring triticale field emergence

Sources of variation	Degrees of freedom	Days after sowing 14	16	19	21	Maguire's coeff.
Blocks	6	3.5 ns	3.8 ns	2.9 ns	2.3 ns	2.9 ns
Years (A)	2	47.4**	37.2**	36.2**	41.3**	38.2**
Degrees of sprouting (B)	4	19.0 ns	38.1**	50.7**	46.9**	49.4**
Interaction:						
AxB	8	19.1**	14.2**	2.5**	2.4**	2.7**
Error	24	3.0	1.2	0.7	0.4	0.4
Cultivars (C)	2	0.0 ns	0.0 ns	0.0 ns	0.0 ns	0.0 ns
Interaction:						
AxC	4	1.0*	0.1	1.4**	1.3**	0.9**
BxC	8	0.0 ns	0.0 ns	0.0 ns	0.1 ns	0.0 ns
AxBxC	16	0.2 ns	0.0 ns	0.5 ns	0.2 ns	0.4 ns
Error	60	6.8	5.4	5.4	5.1	5.2

* - significant at α=0,05; ** - significant at α=0,01; ns – not significant

Table 2. Percentage of variance components and significance of the sources of variation for yield components and the yield of spring tiritcale seeds

Sources of variation	Degrees of freedom	Number of spikes per m^2	Seed weight per spike	Thousand seeds weight	Yield per m^2
Blocks	6	4.1 ns	10.3 ns	1.8 ns	3.7 ns
Years (A)	2	12.2**	44.2**	0.0 ns	22.9**
Degrees of sprouting (B)	4	40.7**	0.2**	20.5**	38.0**
Interaction:					
AxB	8	8.9**	20.1**	11.4*	8.9**
Error	24	8.4	0.0	10.1	3.6
Cultivars (C)	2	1.6**	0.0 ns	0.0**	2.8**
Interaction:					
AxC	4	3.1*	0.0 ns	18.2**	7.9**
BxC	8	0.4 ns	0.4 ns	1.4 **	0.6 ns
AxBxC	16	0.2 ns	2.5 ns	16.0 **	1.7 ns
Error	60	20.3	22.2	20.8	9.8

* - significant at α=0,05; ** - significant at α=0,01; ns – not significant

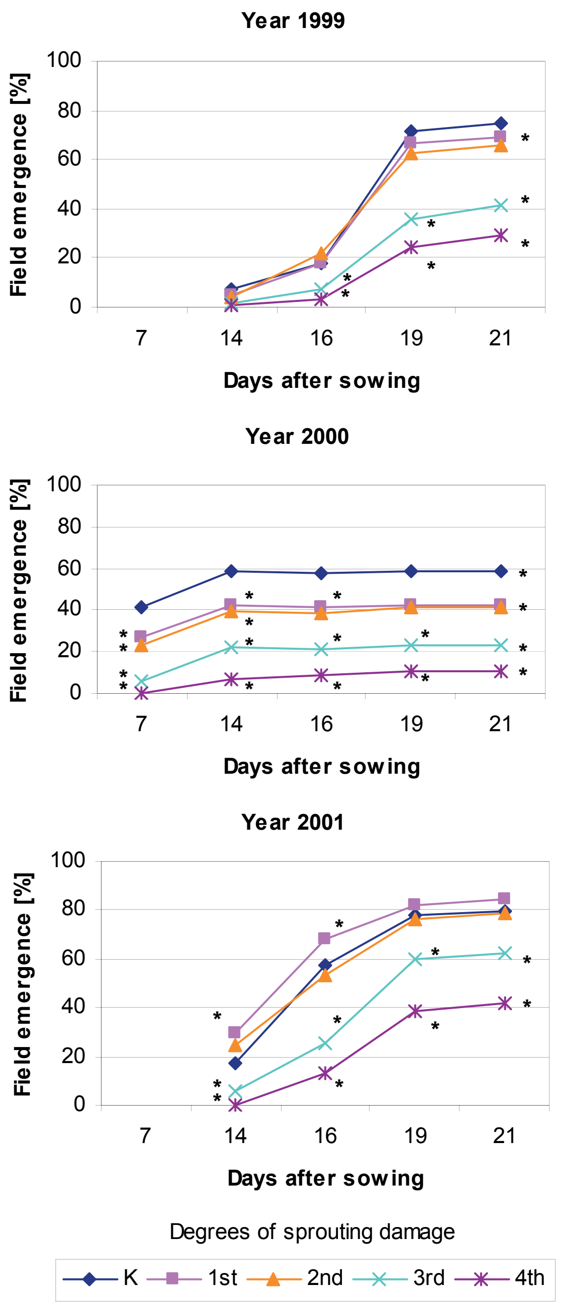

Figure 1. Field emergence of spring triticale seeds with sprouting damage
* - values differing significantly from the control (Dunnett's t-test, α=0.05)

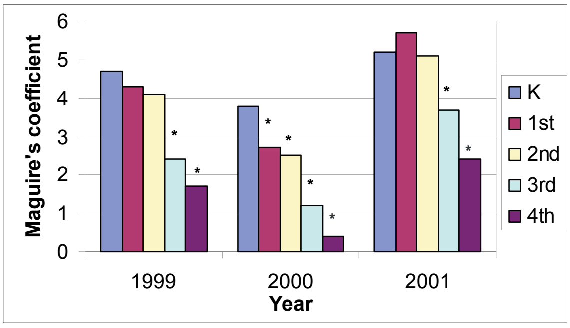

Figure 2. Field emergence rates of spring triticale seeds with sprouting damage (K, 1st, 2nd, 3rd 4th)
* - values differing significantly from the control (Dunnett's t-test, α=0.05)

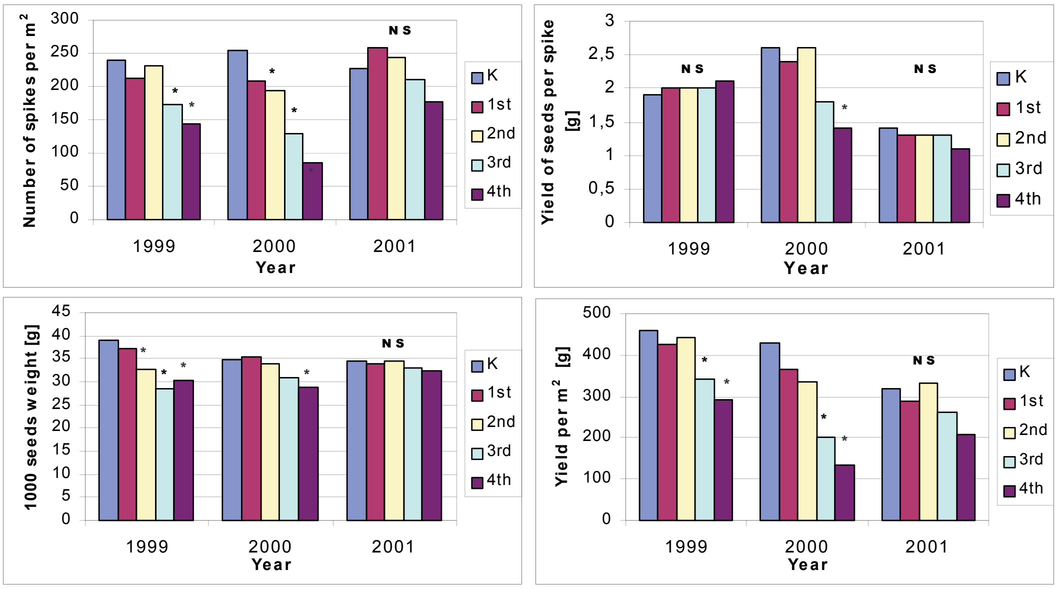

Figure 3. Effect of years and sprouting damage (K, 1st, 2nd, 3rd 4th) on elements of the structure of yield and the yield of spring triticale seeds
* - values differing significantly from the control (Dunnett's t-test, α=0.05)

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