Competitive ability of wheat cultivars with wild oats depending on nitrogen fertilization

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Agronomie 21 (2001) 119–125

Original article

Competitive ability of wheat cultivars with wild oats depending on nitrogen fertilization

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(Received 6 March 2000; revised 9 October 2000; accepted 12 October 2000)

Abstract – In a field experiment, wheat (*Triticum aestivum* L.) grew with the infesting weed wild oat (*Avena sterilis* ssp. *sterilis* L.) in semi-arid conditions. Both species were affected by the drought conditions, although drought caused more damage to the growth and seed production of *A. sterilis* than of the wheat. Both species benefited from nitrogen fertilization, but much more so in the year when water was not a limiting factor. In comparison with the semi-dwarf cultivar (Anza), the tall wheat cultivar (Pané 247) is competitively superior to *A. sterilis*. This competitive superiority was related more to the height of the wheat plant and supposed competition for light than to tiller production. The competition affected the production of *A. sterilis* panicles and spikelets. In addition, the height and competitive ability of the tall wheat cultivar increased more than that of the semi-dwarf cultivar with increasing nitrogen doses. The choice of the wheat cultivars and the use of N doses depending on the climatic conditions is discussed with regard to the control possibilities for *A. sterilis*.

***Avena sterilis* / climate / nitrogen fertilization / wheat cultivar**

Résumé – Aptitude à la compétition des variétés de blé avec la folle avoine en fonction de la fertilisation azotée. Du blé (*Triticum aestivum* L.) infesté avec la mauvaise herbe folle avoine (*Avena sterilis* ssp. *sterilis* L.) a été cultivé en conditions semi-arides de champ. Les deux espèces ont été affectées de la même façon par les conditions de sécheresse bien que celles-ci aient causé plus de dommages à la croissance et à la production de graines chez *Avena sterilis* qu'au blé. Les deux espèces ont bénéficié de la fertilisation azotée mais beaucoup plus l'année où l'eau n'était pas un facteur limitant. En comparaison avec la variété semi-naine (Anza), la variété de blé haute (Pané 247) est supérieure à *Avena sterilis* du point de vue de la compétition. Cette supériorité compétitive est plus liée à la hauteur du blé, et suppose une concurrence pour la lumière, qu'à la taille du talle. La concurrence a affecté la production d'épis et d'épillets de la folle avoine. De plus, la hauteur et l'aptitude à la compétition de la variété de blé haute ont plus augmenté que celles de la variété semi-naine avec des doses d'azote croissantes. Le choix de la variété de blé et l'usage de doses d'azote en fonction des conditions climatologiques est discutée par rapport aux possibilités de contrôle de la folle avoine.

***Avena sterilis* / climat / fertilisation azotée / variété de blé**

1. INTRODUCTION

Avena sterilis ssp. *sterilis* L. is a common cereal-infesting weed in Mediterranean areas. With the aim of reducing herbicide dependence in weed control with cereals, it is important to develop appropriate weed management strategies for farmers. Among these strategies there is the use of strongly competitive cultivars and fertilization. Some authors state that wheat cultivars do not differ with regard to their ability to suppress the growth

Communicated by Gérard Guyot (Avignon, France)

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of *Avena* spp. as much in field conditions [7] as under controlled conditions [4], while for other authors taller wheat cultivars are more competitive than lower varieties [13, 14] as they compete for light [8, 14].

It has been found that the crop attributes more strongly correlated with the competitive ability of wheat with *Lolium rigidum* Gaud. were plant height, the number of tillers, early biomass production and leaf size, all of them related to the shading ability [9]. As a result of cereal shading, the above-ground weight, seed number and height of *Avena fatua* L. becomes reduced [12]. For other authors [1], the plant height and biomass accumulation per wheat area during early growth were better attributes than the number of tillers to predict the competitive ability of the crop with *Avena* spp. Such early dry matter accumulation per crop area is related to the rate of early vegetation cover [10].

A similar positive response of cereals and *Avena* spp. [6, 11] or a greater response of *Avena fatua* than wheat [15] was found when nitrogen fertilization increases. The greater response to nitrogen of the weed, related to nitrogen uptake and vegetative growth produced a decrease of crop yield as nitrogen fertilization increased [15]. According to some authors, a higher nitrogen dosage increased the ability of the cereal to suppress the weeds [5]. Others found that the effect of nitrogen fertilization on the yield of wheat infested with *A. fatua* depended on the relative density of the weed. Therefore, nitrogen fertilization increased wheat grain yield only when the weed density was below 1.6% of the total plants per area [2]. In addition, the nitrogen dosage increased the growth of cereal cultivars, but did not change the ranking of the different competitive abilities with *A. fatua* [11].

The aim of the present study was to determine whether the climatic conditions and the nitrogen doses could change the competitive ability of wheat cultivars with regard to *A. sterilis.*

2. MATERIALS AND METHODS

Field experiments were conducted in a typical semiarid area of the Toledo province (Spain), traditionally cultivated with cereals infested by a very homogeneous population of wild oats (*Avena sterilis* ssp. *sterilis* L.). The experiments were in the years 1995/96 and 1996/97, each year on different plots with similar infestation. Wheat (*Triticum aestivum* L.) cultivars, i.e. Pané 247 (tall and standard in the area) and Anza (semi-dwarf of Mexican origin), were sown in November of the two years. The sowing doses were 152 and 144 kg·ha^{-1} of Pané 247 and Anza seeds respectively, in order to obtain a similar number of wheat plants per m^{-2} (255±16) of both cultivars. The first peak of wild oats emergence occurred at the same time as that of wheat, on 13 December, 1995 and 25 November, 1996, being similar. The number of *A. sterilis* plants m^{-2} that emerged in the two autumns was 15±3 and 16±3, being 5.5 and 5.9% of the total plants per area, respectively. Such infestations are normal in the cereal fields of the region and cause a loss of the wheat grain yield of between 20 and 40% [3].

The soil was poor in nitrogen (NO_3^- = 16 ppm). Before sowing 700 kg·ha^{-1} of fertilizer, 0- 14- 7 (N-P-K) were added in equal proportion to each plot. The nitrogen fertilization treatments were 50, 100, 150, 200 or 250 kg N·ha^{-1} plus a control plot without nitrogen. Nitrogen fertilization took the form of calcium ammonium nitrate, 60% distributed before sowing the wheat and 40% at the beginning of tillering, i.e. growth stage 22 [16]. A randomized block design was used with four replicates per treatment, which produced a total of 48 plots. The plot size was 2 × 4 m. On 10 and 26 February, 1996 and 1997 respectively, 3.5 L·ha^{-1} of chortoluron (50%) was applied to the plots to control the dicot weeds and wild oats which emerged during the winter (second peak of emergence). So, these wild oats were controlled, the plants with one or two leaves, whereas wheat was in advanced tillering. At this time, the wild oats that emerged in the first peak were at the beginning of tillering, 23 and 22 growth stages [16] in 1996 and 1997 respectively. After February, there was no significant weed emergence, due to the combined effect of light rainfall and high cover crop. So, wheat cultivars grew until ripening only with wild oats coming from the first peak of emergence.

At wheat ripening, 26 June and 3 July, in 1996 and 1997 respectively, the crop and weed plants were cut at soil level in a square meter of each plot. The number of wheat tillers were recorded as well as the grain, straw and above-ground weight, with the above-ground weight being the sum of grain and straw weight. The weed straw weight was also measured. The number of *A. sterilis* panicles and spikelets were measured just before the spikelets fell off.

The plant height was measured from the soil surface to the tip of the growing point. At ripening in 1995/96, only the average height reached by the wheat plants as a whole was measured in each of the plots, but the height of the *A. sterilis* plants was not measured. In 1996/97, both the wheat and *A. sterilis* plant height of fifteen plants of each species were measured in all the plots. This measurement was taken in March, when the wheat plants had totally expanded their leaves, in boot, i.e. growth stages 45 to 49, and wild oats were in stem extension, i.e. growth stages 32 to 33 [16].

Table I. Climatic conditions in the years 1995/96 and 1996/97.

	N	D	J	F	M	A	M	J
1995/96								
Rainfall (mm)	70.9	151.5	102.8	22.3	42.5	12.3	106.4	13.4
Mean temp. (º C)	11.6	8.8	8.4	6.4	9.7	13.5	15.9	23.1
1996/97								
Rainfall (mm)	79.0	150.9	113.7	2.3	0	47.6	69.2	5.4
Mean temp. (º C)	10.0	7.8	7.0	9.4	12.8	15.6	16.9	19.9

3. RESULTS

3.1.Effects of the year

In the period 1995/96, rainfall conditions were adequate for the development of wheat and *A. sterilis*. The length of the tillering period for wheat and *A. sterilis* were 63 and 59 days, respectively. In 1996/97, with almost no precipitations throughout the months of February and March and with very high temperatures in the same months as well as in April, the tillering and stem extension periods for both species was considerably shortened. So, the duration of tillering was 39 and 30 days for wheat and *A. sterilis*, respectively (Tab. I).

The year had significant effects (P = 0.001) on both species with regard to all attributes measured, which were lower in 1996/97 than in 1995/96. In global terms, the drought caused more damage to the growth and seed production of *A. sterilis* than that of wheat and more to the seed production than to the growth of both species (Tab. II).

3.2. Effects of wheat cultivar

The wheat cultivar had significant effects (at least at P = 0.05) on all wheat growth and seed production attributes, but only on the number of *A. sterilis* panicles and spikelets and the spikelets' weight. Anza cv. (the semi-dwarf variety) produced a greater number of tillers and higher grain yield, but less straw weight and above-ground weight than Pané 247 cv. (the tall variety). *A. sterilis* growing in the company of Pané 247 cv. had a lower number of panicles and spikelets, and a lower spikelet weight than when it grew with Anza cv. (Tab. III).

Table II. Effects of the year on straw and seed production of wheat and *A. sterilis.*

Plant attributes	Year 1995/96 (wet)	Year 1996/97 (dry)	∇	SEM	Prob. level (%)
Wheat					
Grain yield (g·m^{-2})	510.5	172.2	66.3	15.9	***
Straw weight (g·m^{-2})	855.2	517.1	39.5	32.9	***
A.sterilis					
Weight spikelets (g·m^{-2})	33.5	5.2	84.4	1.2	***
Straw weight (g·m^{-2})	52.4	15.2	71.0	2.1	***

∇: Plant attributes decrease in % of dry year in relation to wet year.
SEM = standard error of the mean.
***: significant at the 0.1% probability level.

3.3. Effects of N doses

The nitrogen fertilization had significant effects (P = 0.01) on all the growth and seed production attributes of both wheat and *A. sterilis*. A similar positive response was obtained in both species to nitrogen fertilization.

3.4. Effects of the year × wheat cultivar

There were significant effects (P = 0.05) of the interaction year × wheat cultivar on all the wheat growth and grain yield attributes as well as on the number of *A. sterilis* panicles and spikelets. Both wheat varieties grew and produced more grain in 1995/96 than in 1996/97, but compared to Pané 247 cv. in 1995/96, the tiller production and grain yield of Anza cv. was higher, while straw and above-ground weight were the same. With regard to Anza cv. in 1996/97, Pané 247 cv. was superior in straw weight and above-ground weight, while the number of tillers and grain yield were the same (Tab. IV).

The number of panicles and spikelets of *A. sterilis* was lower in 1996/97 than in 1995/96 and in both years

Table III. Effects of wheat cultivar on growth and seed production of wheat and *A. sterilis* (means of the two years).

Plant attributes	Wheat cultivar Anza	Wheat cultivar Pané 247	SEM	Prob. level (%)
Wheat				
Number of tillers m^{-2}	316.0	272.9	10.5	**
Grain yield ($g \cdot m^{-2}$)	366.3	316.4	20.2	*
Straw weight ($g \cdot m^{-2}$)	630.1	742.1	40.3	*
Above-ground weight ($g \cdot m^{-2}$)	995.6	1058.5	30.2	*
A. sterilis				
Number of panicles m^{-2}	40.4	33.6	2.1	*
Number of spikelets m^{-2}	364.0	303.0	23.1	*
Spikelets weight ($g \cdot m^{-2}$)	20.0	18.8	0.5	*

SEM = standard error of the mean.
* , **: significant at the 5% and 1% probability level respectively.

Table IV. Effects of the year × wheat cultivar on growth and seed yield of wheat.

Wheat attributes	Year 1995/96 Anza	Year 1995/96 Pané 247	Year 1996/97 Anza	Year 1996/97 Pané 247	SEM
Number of tillers m^{-2}	362.3	287.6	269.6	258.2	14.7
Grain yield ($g \cdot m^{-2}$)	547.1	473.9	185.6	158.8	30.3
Straw weight ($g \cdot m^{-2}$)	815.1	895.2	445.1	589.1	60.5
Above-ground weight ($g \cdot m^{-2}$)	1362.2	1369.1	630.7	747.9	44.4

SEM = standard error of the mean.

A. sterilis produced less panicles and spikelets growing with Pané 247 cv. than with Anza cv. (Fig. 1).

3.5. Effects of the year × N doses

The interaction year × N doses had significant effects ($P = 0.05$) on all the growth and seed production attributes of wheat and *A. sterilis*. Thus, an increase of the nitrogen doses produced a positive and similar response of the attributes in both species and years, but much greater in 1995/96 than in 1996/97.

3.6. Effects of the wheat cultivar × N doses

The interaction wheat cultivar × N doses had significant effects ($P = 0.05$) on the number of wheat tillers, grain yield and straw weight as well as on the number of *A. sterilis* panicles and spikelets. An increase of the nitrogen doses produced an increase of these attributes in both cultivars, although more noticeably in Anza cv. than in Pané 247 cv., especially with regard to the number of tillers and grain yield. On the other hand, when the nitrogen doses were increased, the *A. sterilis* reproductive attributes increased, but the increase was lower when the weed grew with Pané 247 cv. than with Anza cv. (Fig. 2).

In both 1995/96 and 1996/97, the interaction wheat cultivar × N doses had significant effects ($P = 0.05$) on the wheat plant height. When the nitrogen doses increased, the height of both cultivars increased, although more noticeably in Pané 247 cv. than in Anza cv. Figure 3 shows the average height reached by the wheat plants upon ripening in response to the nitrogen doses in 1995/96. In 1996/97 the plant height, measured in wheat boot, was limited by the drought during February and March, the time when the tillering and stem extension of wheat and *A. sterilis* was. The plant height response of the two wheat cultivars to nitrogen doses is shown in Figure 4. In this year, there was no significant interaction of wheat cultivar × N doses on the plant height of *A. sterilis*. With increasing nitrogen doses, the weed grew to the same height in both wheat cultivars (Fig. 4).

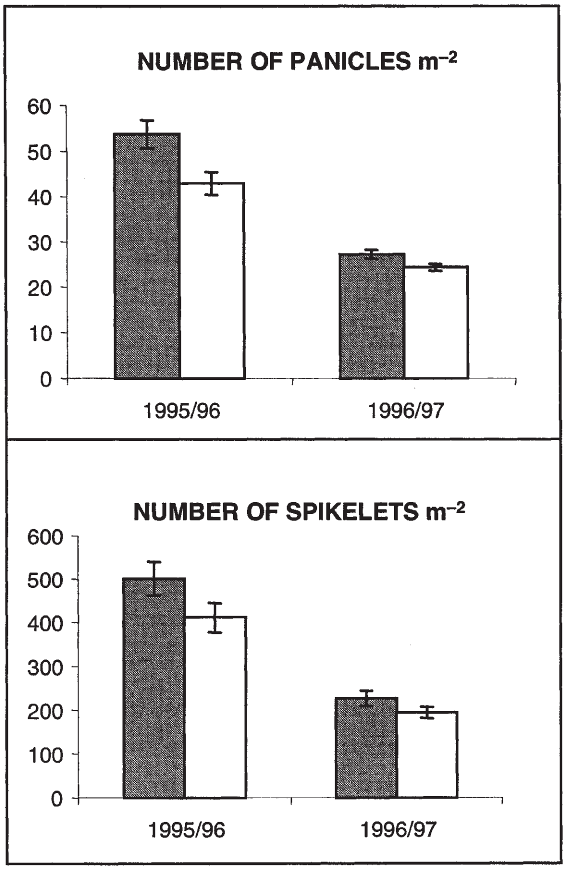

Figure 1. Number of panicles and spikelets of *A. sterilis* growing with Anza ▩ and Pané 247 ☐ wheat cultivars in 1995/96 and 1996/97.

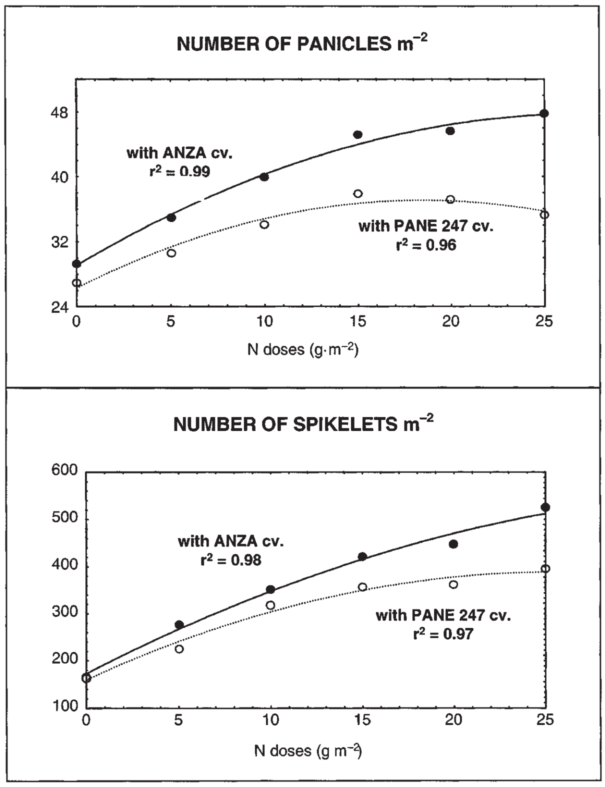

Figure 2. Effects of N doses on number of panicles and spikelets of *A. sterilis* growing with Anza and Pané 247 wheat cultivars.

3.7. Effects of the year × wheat cultivar x N doses

This interaction had significant effects (P = 0.05) on the number of wheat tillers, grain yield and above-ground weight, but it had none on any *A. sterilis* attributes. Increasing nitrogen doses produced a general increase of the number of tillers and grain yield in both years, more so in wheat Anza cv. than in Pané 247 cv., and noticeably much more in 1995/96 than in 1996/97.

Figure 5 shows that the wheat cultivars did not reach their productive limit with the nitrogen doses tested in 1995/96 (a wet year), while with regard to Pané 247 cv., Anza cv. increasingly showed its grain production superiority with increasing N doses. However, in 1996/97 (a dry year), Anza cv. and Pané 247 cv. reached the productive limits with 157 and 203 kg N·ha^{-1} respectively, while the grain yield decreased at higher doses.

In addition, while the above-ground weight of both wheat cultivars was similar with each of the nitrogen doses in 1995/96, this attribute was higher in Pané 247 cv. than in Anza cv. with all nitrogen doses in 1996/97.

4. DISCUSSION

The drought conditions affected both species, but *A. sterilis* was proportionately more damaged by the drought in tillering and stem extension than wheat. The seed production was also more damaged by the drought than the straw weight in both species.

The fact of having obtained a lower production of panicles and spikelets with *A. sterilis* when it grew with a tall wheat cultivar (Pané 247) rather than with a semi-dwarf cultivar (Anza) allows the statement that there is a competitive superiority of the tall cultivar, as has already been observed [13,14].

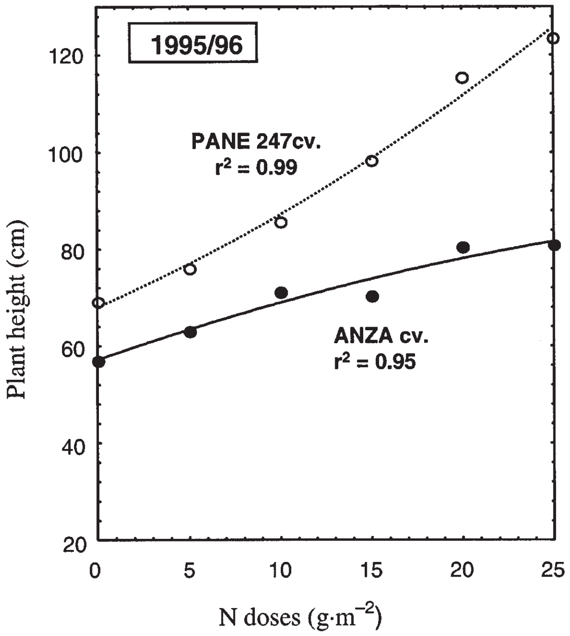

Figure 3. Effects of N doses on plant height of wheat cultivars measured at ripening in 1995/96.

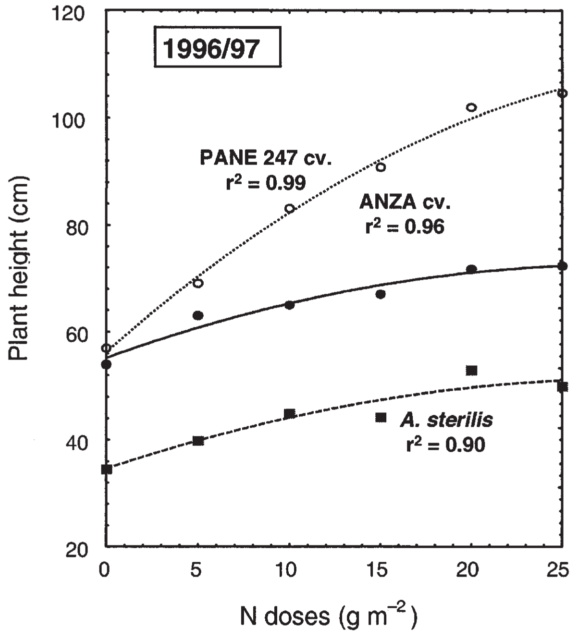

Figure 4. Effects of N doses on plant height of wheat cultivars and *A. sterilis* measured in boot of wheat in 1996/97.

In previous studies it was established that the competitive ability of the cereal for light was related to attributes such as plant height, number of tillers and early biomass production [9]. In addition, plant height and early biomass accumulation were more important attributes than the number of tillers to predict cereal competitiveness in relation to the weed [1]. In this study it is found that plant height was the attribute related to the competition. This statement is based on the fact that both in 1995/96 (a wet year) and in 1996/97 (a dry year) the production of panicles and spikelets of *A. sterilis* was lower when it grew with the tall cultivar than when it grew with the semi-dwarf cultivar. Wheat attributes such as the number of tillers and early biomass accumulation did not show any relation to the reproductive attributes of wild oats. Thus, in 1995/96 the number of tillers was higher in Anza cv. than in Pané 247 cv. And in 1996/97 it was the same in both cultivars: With regard to early biomass accumulation, both species, with the same leaf architecture – prostrate in tillering – have the same phenology up to the beginning of stem extension, the only difference being the tiller production. From the beginning of stem extension, i.e. growth stage 31 [16], and until ripening, however, Pané 247 cv. surpassed Anza cv. in height. From their emergence until the expansion of *A. sterilis* panicles, both cultivars surpassed it in height.

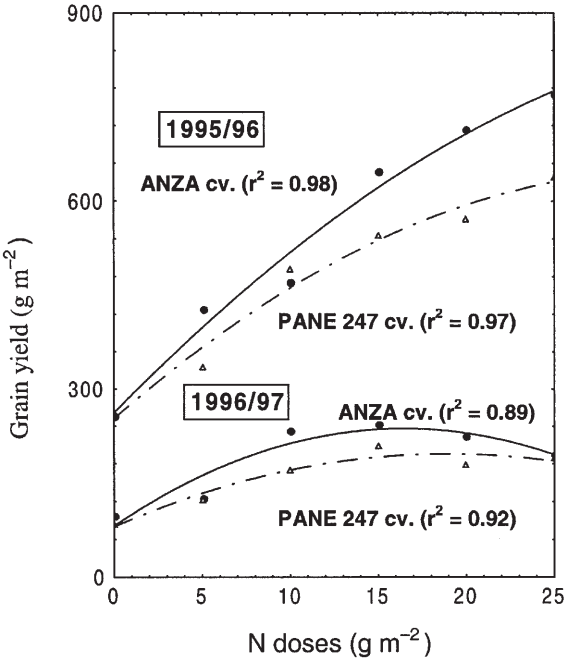

Figure 5. Effects of N doses on grain yield of wheat cultivars in 1995/96 and 1996/97.

The plant height measurements carried out in boot of wheat were used as a reference for the differences of this attribute between species and cultivars.

The height of the crop was therefore responsible for the competition for light with the weed, confirming what was found by other authors [8, 9, 14]. This caused the production of panicles and spikelets of *A. sterilis* to decrease, similar to what was found previously for *A. fatua* [12].

The same as in previous studies [6, 11], but unlike others [15], nitrogen fertilization benefited cereals in the same way as wild oats and the nitrogen response was greater in the wet year than in the dry year.

As was found earlier, increased nitrogen doses increased the height of the wheat cultivars [11]. This occurred in both years, but in 1996/97 it is possible to confirm not only the superiority of the Pané 247 cv. response to nitrogen fertilization if compared with Anza cv., but also the positive response of *A. sterilis* plant height to nitrogen fertilization.

On the other hand, contrary to what was found earlier [11], nitrogen doses were indeed capable of changing the competitive ability of the cultivars tested. Thus, an increase of the nitrogen doses was capable of proportionately increasing the height of the tall cultivar (Pané 247) more than that of the semi-dwarf cultivar (Anza). As the height of *A. sterilis* grew with the nitrogen doses in the same proportion when it grew with either wheat cultivar, the differences of height in favour of wheat compared with the weed and the competitiveness for light by Pané 247 cv. increased with the nitrogen doses.

In the wet year, there was a substantial response of the wheat grain yield to the nitrogen doses, the *A. sterilis* plant density being between 5.5 and 5.9% of the total plant density. This result differs from that obtained in irrigated field conditions where there were increases in wheat grain yield only when *A. fatua* plant density was below 1.6% of the total plant density [2]. Due to the increase of *A. sterilis* seed production in response to increased nitrogen doses, high fertilization will lead to high wheat grain productivity and massive increase of *A. sterilis* infestation if no control measures are introduced. This will occur particularly with semi-dwarf cultivars. The seed production of both species also increased in response to nitrogen doses in the dry year, but less so than in the wet year. Always, the use of a tall wheat cultivar favoured the control of the weed. Whatever the case, it is necessary from an economic point of view to evaluate the cost of nitrogen fertilization and use of herbicides for every cultivar to produce a certain grain yield in accordance with the climatic conditions.

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