

## The Influence of Phosphate Treatment on Chromosome Segregations and Tetrad Regularity and Using Tetrads in Determination of Regular Meiosis Diploid and Autotetraploid Meadow Fescue (*Festuca pratensis* Huds.)

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**Abstract:** This study was carried out under greenhouse conditions in 1994-1995. The influence of phosphate treatments (0, 1, 2, 3 and 4g P<sub>2</sub>O<sub>5</sub>/pot) on chromosome segregation at the first anaphase (AI) and tetrad regularity in plants of diploid Senu variety of meadow fescue (*Festuca pratensis* Huds.) and its artificial autotetraploid were studied. In addition, the relationship was determined between balanced AI segregations and regular tetrads with respect to regular meiosis.

AI segregations were often balanced in eutetraploids but the frequency of balanced groups was found to be lower than that of the diploids. The difference between diploid and eutetraploid in terms of the frequencies of balanced cells and the frequency of cells with laggards at AI was found to be significant. The frequencies of cells with different AI segregations showed no difference under various phosphate treatments in the two ploidy levels.

The number of micronuclei per tetrad (M/Q) was higher in eutetraploids than that of diploids whereas the percentage of regular tetrads was lower in the formers. The differences were significant between diploids and eutetraploids in terms of these two characteristics. On the other hand, the difference was significant between the phosphate treatments in terms of the percentage of regular tetrads in diploids and eutetraploids.

In both diploids and eutetraploids, there was positive and significant correlation between the frequency of balanced AI cells and the percentage of regular tetrads whereas negative and highly significant relationship between the former and M/Q was noted.

### Diploid ve Autotetraploid Çayır Yumağında Kromozom Ayrılışları ve Tetrad Düzenliliği Üzerine Fosfat Uygulamasının Etkisi ve Düzenli Meiosisın Belirlenmesinde Tetradların Kullanılması

**Özet:** Bu araştırma 1994-1995 yıllarında sera koşullarında yürütülmüştür. Çayır yumağı (*F. pratensis* Huds.)'nin diploid Senu çeşidi ve onun yapay autotetraploid bitkilerinde anafaz I (AI)'deki kromozom ayrılışı ve düzenli tetradlar üzerine fosfat uygulamalarının (0, 1, 2, 3 ve 4 g P<sub>2</sub>O<sub>5</sub>/saksı) etkisi incelenmiştir. Ayrıca, düzenli meiosis yönünden dengeli AI ayrılışları ve düzenli tetradlar arasındaki ilişki belirlenmiştir.

Eutetraploidlerde düzenli AI ayrılışları sıklıkla dengeli olmuş fakat dengeli grupların sıklığının diploidlerdekinden daha düşük olduğu bulunmuştur. Dengeli hücrelerin sıklığı ve gecikenler bulunduran hücrelerin sıklığı yönünden diploid ve eutetraploidler arasındaki farkın önemli olduğu bulunmuştur. Farklı AI ayrılışlarının sıklıkları değişik fosfat uygulamaları altında farklılık göstermemiştir.

Tetrad başına çekirdekci sayısı (M/Q) eutetraploidlerde diploidlerden yüksek olmasına karşın düzenli tetradların yüzdesi eutetraploidlerde daha düşük olmuştur. Bu iki özellik yönünden diploidler ve eutetraploidler arasındaki farklılıklar önemli olmuştur. Diğer taraftan, düzenli tetradların yüzdesi ve M/Q yönünden fosfat uygulamaları arasındaki fark diploidler ve eutetraploidlerde önemli olmuştur.

Dengeli AI hücrelerinin sıklığı ve düzenli tetradların yüzdesi arasında olumlu ve önemli ilişki olmasına karşın ilk özellik ve M/Q arasında hem diploidlerde hem de eutetraploidlerde olumsuz ve çok önemli ilişki bulunmuştur.

### Introduction

For many years polyploidy has been of great interest to breeders in several countries. However, the fertility in all induced autopolyploids has more or less decreased as compared to the corresponding diploid material. Increased yield may be obtained by increasing fertility and tillering capacity, and intensive selection for higher fertility seems to be somewhat successful. As a rule, good

fertility seems to be correlated with regular meiosis (1, 2). Consequently intense selection of plants having a regular meiosis should be effective in producing "tetra" - populations with higher seed fertility (2).

Several attempts have been made to investigate the relationship between the seed fertility and the regularity of the meiosis in different crop species (3, 4, 5). It has been reported that selection for increased seed fertility

over a period of seven years in a newly derived tetraploid Petkus population resulted in a more regular meiosis shown by a decrease in the percentage of cells with laggards at AI, a decrease in the number of laggards per cell, and a similar decrease in the frequency of tetrads with micronuclei (1). On the other hand, relatively little information has been published on chromosomal irregularities and the relationship of these irregularities in different stages of the meiotic divisions. Nevertheless, a knowledge of the extent of occurrence of such irregularities which result in chromatin loss or in unequal chromosomal distribution to the spores is of considerable importance. Myers and Hill (6) found variation in chromosomal irregularities during meiosis in different plants of three naturally occurring autotetraploid grasses and showed relationships between the irregularities occurring in different stages of meiosis.

Many studies have confirmed the deleterious effects of high temperature treatments on chromosome pairing behaviour (7, 8, 9). Again, other investigations have demonstrated the effects of ionic environment (10) and mineral treatments on chromosome pairing (11, 12, 13, 14). Law (11) demonstrated the role of potassium in the increase of chiasma frequency and chiasma stability in *Lolium temulentum*. Similar results were obtained in response to phosphate treatments in diploid barley (14) and rye (12). These studies were exclusively confined to diploid materials and very little information is available about the effects of environmental factors on autopolyploids. Studies on the effects of environmental factors in autopolyploids are of interest for two reasons. First, such investigations may provide a better understanding of chromosome pairing and segregation and meiotic stability in autopolyploid. Second, changes in environmental conditions, especially nutrient treatments (11, 12, 14), have been shown to increase balanced chromosome segregation which in turn is an important component of meiotic regularity (4, 5, 15, 16). In addition, based on the evidence that heritable changes may sometimes be induced by chemical or mineral treatments (9, 17, 18, 19), it is perhaps too early to discount the possibilities of meiotic improvement in autopolyploids through the influence of external factors.

The effects of phosphate treatments on the pairing of chromosomes and chromosome arms bound at the first metaphase in diploid and autotetraploid meadow fescue have already been described (20). In the present investigation the effects of phosphate treatments on chromosome segregation at AI and the percentage of regular tetrads in the advanced generation of autotetraploid meadow fescue and its representative

diploid cultivar were studied. Furthermore, the relationship was determined between regular AI segregation and regular tetrads for identifying the possibilities of using tetrad regularity as a selection criterion in the meiotic regularity and stability.

## Material and Methods

### Material

This study was carried out in the greenhouse of Agronomy Department of Agricultural Faculty, Atatürk University in 1994-1995. In this study, the Danish diploid cultivar Senu of meadow fescue (*Festuca pratensis* Huds.) and its advanced generation ( $C_6$ ) of artificial autotetraploid (Tetra-Senu) plants were used (20).

For this study, sandy-loam field soil (20) and clay pots were used and each pot was filled with air dried soil of about 4.600 g. Ammonium sulphate with 21% N and triple superphosphate with 42-44 %  $P_2O_5$  content were used as chemical fertilizers.

### Methods

#### Experimental Treatments

Plants used in the trial were primarily grown in the wooden growth boxes. Then a single seedling was raised in each pot and one plant was randomly taken from in each ploidy level. Since it was intended to establish clones of individual genotype in the two ploidy levels, the plants were raised in the greenhouse for a longer period for vegetative growth and tillering. After reaching certain size, clones taken from the parent plants were transplanted into the pots one by one on March, 28, 1994. Each clone had sufficient root system to establish itself when transplanted into individual pots. Clones of a large number of genotype were raised in this way for use in the experiment. In the first year, same amounts of N and  $P_2O_5$  (3.0 and 2.3 g/pot respectively) were applied to all the plants and the whole phosphorus and the half of nitrogen were mixed with the soil in the pots during transplantation process. The remaining half of the nitrogen was applied at mid-summer, namely on August, 5, 1994. In the second year; in addition to 3.0 g N/pot year standard application, 0.0, 1.0, 2.0, 3.0 and 4.0 g/pot year  $P_2O_5$  doses were in turn applied to all plants at random. The whole of  $P_2O_5$  doses and the half of N were applied on March, 3, 1995. The remaining half of the N was applied in the beginning of anthesis period on May, 10, 1995. The plants were appropriately irrigated with tap water to keep the soil steadily at the field capacity level. Necessary attention was paid to the irrigation in order to prevent loss of water caused by drainage.

### Cytological Observations

In each ploidy level, 20 clone plants which were taken from the same single genotype were grown under greenhouse conditions. The plants were kept in heated greenhouse in autumn and winter (from 15 October-1 March) and unheated ones under natural conditions for the rest of the year. Suitable inflorescences for meiotic studies were collected from each plant in each treatment and pickled in Carnoy solution for fixation for about two days. Then the inflorescence samples were transferred into 70% ethanol and kept in a household refrigerator until the time of study (14, 21). Following the fixation of the samples, slides were made by aceto-orceine squash method. One of the anthers was squashed and mounted in aceto-orceine solution of 2% (3, 21, 22) chromosome segregation at AI were determined in 30 pollen mother cells (PMC) in each plant (5). In addition, the percentage of regular tetrads (tetrads without micronuclei %) were scored in 200 PMC's of each plant (3, 8), giving a good idea of the regularity of the meiosis.

### Experimental Design and Analysis of Data

This experiment was arranged in a completely randomized factorial design with 4 replications (23). Two ploidy levels and five phosphate doses were used in the research. The cytological investigations were made on samples which were taken from the plants in the second year of experiment. Data of diploid and tetraploid plants were analyzed according to the experimental design. The comparison of the mean values of phosphate treatments in two ploidy levels were made by using Duncan test (23).

## Results and Discussion

### AI Segregations

The segregation at AI was normal in all cells of diploid studied in 7 out of the 20 genotype under consideration

(Fig. 1 a). But different segregation irregularities were observed in some cells of all eutetraploid plants. The number of the different types of chromosome distributions at AI was separately analysed in both diploid and eutetraploids. It is obvious, however, that they are not independent of one another. Nevertheless, the significant differences with respect to all types of distributions indicate an effect of the diploid and eutetraploid genotypes upon the separating pattern in the clone plants of two ploidy levels of meadow fescue. In eutetraploids, AI segregations were often balanced (14:14) but the frequency of balanced segregations were found to be lower than that of the diploid plants (7:7). The difference between the diploid and eutetraploid in terms of the frequency of PMC's with normal chromosome groups (7:7, 14:14 respectively) and the frequency of cells with one lagging univalents (7: 6+1<sub>1</sub>, 14:13 + 1<sub>1</sub> respectively) at AI were found to be statistically significant (Table 1; P≤0.01, P≤0.01). Accordingly, AI segregations appeared to be more regular in the diploids than those of eutetraploids and also AI irregularities were found to be lower in the formers. The situation was thus the same as those found in several species by other researchers (4, 5, 21, 24).

Diploid meadow fescue showed mostly a regular AI segregation. Although most cells had balanced chromosome distribution (7:7), unbalanced anaphase groups, lagging and divided univalents (Chr) and dicentric chromatid bridge (Br) were also found (Table 2) (Fig. 1 b, c). The mean frequency of PMC's with balanced segregation or the frequencies of cells with different irregularities at AI showed no difference under various phosphate treatments in diploid plants (Table 2). However, the lowest frequency of normal anaphase groups was found under the control treatment. It appears, nevertheless, that the distribution of chromosomes at AI is primarily determined by the

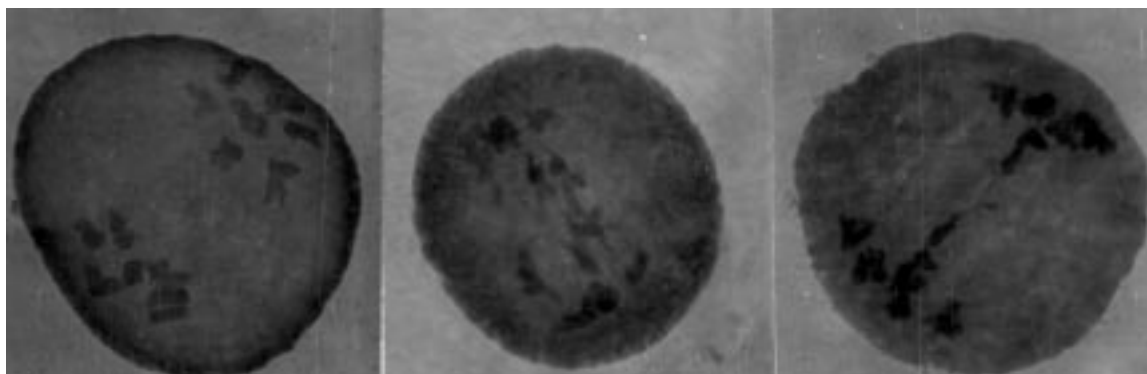


Figure 1. Balanced AI segregations (a), with lagging univalents and dicentric chromatid bridge (b), dicentric chromatid bridge only (c) in the pollen mother cells of diploid meadow fescue (Enl.: 1000 x).

Ploidy Level	Frequency of AI Cells with			Tetrads	
	Balanced Segre.	Laggards	Bridge Only	M/Q	Regular Ted. (%)
Diploid	29.99 a	0.35 b	0.05 b	0.114 b	91.20 a
Tetraploid	27.20 b	1.25 a	0.45 a	0.217 a	88.63 b
Gen. Mean	28.10	0.80	0.25	0.166	89.92

Table 1. The Mean Frequency of Cells With Different AI Segregations and The Mean Percentage of Regular Tetrads and M/Q in Diploid and Eutetraploid Meadow Fescue\*.

\* Mean values within a column are significantly different at the 0.01 level.

Table 2. The Mean Frequencies of Cells with Different AI Segregations and The Mean Percentage of Regular Tetrads and M/Q in Diploid Meadow Fescue.

P <sub>2</sub> O <sub>5</sub> Treat. (g/pot)	Frequency of AI Cells with								Tetrads	
	7	6	6	6	6	6	6	6	Brid Only	Reg. Ted (%)*
Control	28.50	0.25	0.50	0.00	0.25	0.00	0.25	0.25	0.124a	88.88c
1	28.75	0.00	0.50	0.25	0.00	0.25	0.25	0.00	0.116ab	90.25bc
2	29.00	0.25	0.25	0.00	0.25	0.00	0.25	0.00	0.115ab	90.88b
3	29.50	0.00	0.25	0.00	0.00	0.00	0.25	0.00	0.110b	92.88a
4	29.25	0.00	0.25	0.25	0.25	0.00	0.00	0.00	0.108b	93.13a
Gen. Mean	29.00	0.10	0.35	0.10	0.15	0.05	0.20	0.05	0.114	91.20

\* Indicate significance at the 0.01 level and mean values within a column are not significantly different based on Duncan test.

genotypic control. This situation is in agreement with that found in diploid meadow fescue by Simonsen (5).

In eutetraploid meadow fescue, chromosome distributions were generally regular (14:14) at AI (Fig. a, b). In these plants, in addition to unbalanced chromosome segregations (Fig. 2 c), lagging and divided univalents, dicentric chromatid chromatid bridges (Fig. 3 a, b) and fragments caused irregular anaphase segregations. Under various phosphate treatments, there were no significant differences in the mean frequencies of PMC's with balanced segregation or in the mean frequencies of PMC's with all other types of irregularities at AI (Table 3). However, the lowest mean frequency of normal anaphase

groups and the highest mean frequencies of all other types of irregularities were found under the control treatment. Accordingly, it was possible to suggest that the segregation of chromosomes at first anaphase is primarily determined by the genotypic control. Recent studies have shown that the meiotic characteristics in some crop species are subject to the control of the genotype (3, 5, 16, 17, 18, 19). However, it is shown by other researchers that there is an influence of changes in mineral treatments upon some meiotic characteristics (11, 12, 14).

The origin of laggards at anaphase I is of considerable interest. It is well known that univalents and multivalents

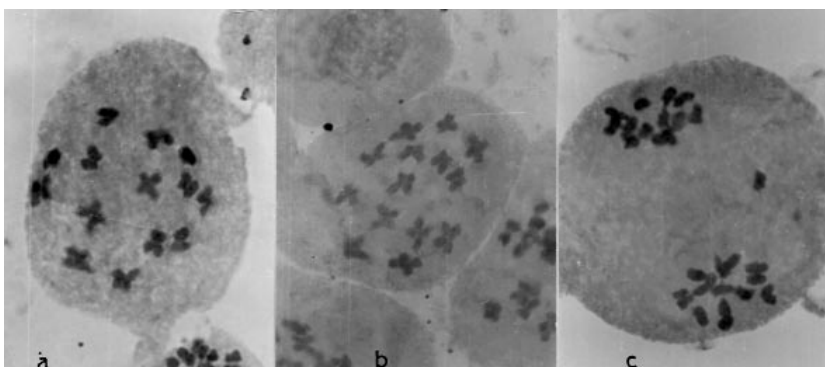


Figure 2. Early AI showing meiotic chromosomes spread on cell plate (a, b), unbalanced AI segregation with lagging univalent (c) in the pollen mother cells of eutetraploid meadow fescue (Enl.: 1000 x).

Table 3. The Mean Frequencies of Cells with Different AI Segregations and The Mean Percentage of Regular Tetrads and M/Q in Eutetraploid Meadow Fescue.

P <sub>2</sub> O <sub>5</sub> Treat. (g/pot)	Frequency of AI Cells with								Tetrads	
	14	13	13	13	13	13	13	13	M/O	Reg. Ted (%)*
Control	14	13	11	2Chr	21	11+2Chr	21+Br	Brid Only	0.228	86.26b
1	14	15	14	14	13	13	13	13	0.216	87.25ab
2	26.25	0.50	1.50	0.00	0.75	0.25	0.75	0.00	0.213	90.00a
3	27.25	0.25	1.25	0.50	0.00	0.25	0.25	0.25	0.215	90.00a
4	27.50	0.50	1.25	0.25	0.25	0.00	0.00	0.00	0.213	89.63a
Gen.Mean	27.00	0.00	1.00	0.00	0.25	0.25	0.50	0.00	0.217	88.63

\* Indicate significance at the 0.05 level and mean values within a column are not significantly different based on Duncan test.

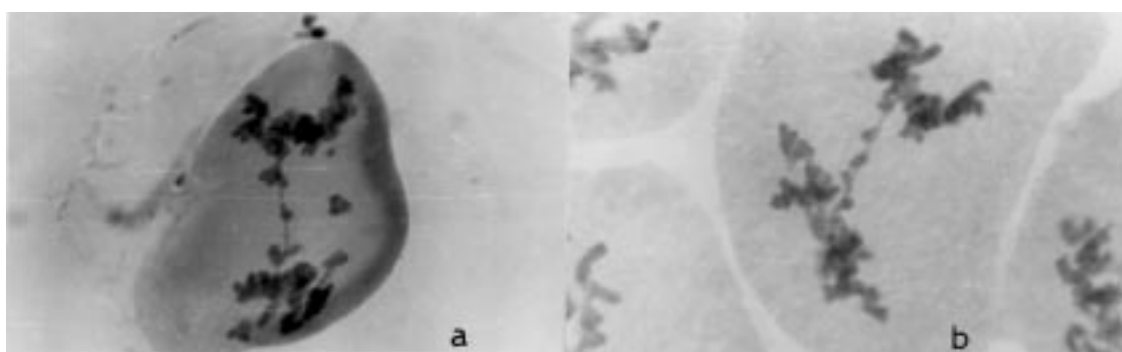


Figure 3. Abnormal AI with lagging univalent and dicentric chromatid bridge (a), with dicentric chromatid bridge only (b) in the pollen mother cells of eutetraploid meadow fescue (Enl.: 1000 x).

are the most common reasons for irregularities at the first anaphase of meiosis in diploids and especially tetraploids (3, 5, 6, 21, 25). Unequal disjunction of the members of multivalents results in unbalanced anaphase groups whereas incomplete distribution often leads to lagging univalents at AI in induced autotetraploids.

#### Tetrads

The amount for chromosome loss was related to the frequency of chromatin material remaining in the cytoplasm of the tetrads outside the normal nuclei. This chromatin material appeared in some quartets as small nucleus or nuclei (dark-staining clumps) and all these chromatin bodies are called micronuclei (6, 26). When the frequency of AI cells with abnormal segregation (all segregations deviating from the normal, 14:14) was considered, a similar result appeared as far as irregular tetrads were concerned. In eutetraploid meadow fescue, the number of micronuclei per tetrad (M/Q) was higher than that of diploid while the frequency of regular tetrads was lower in the former than that of the latter.

Accordingly, the differences were significant between the diploid and eutetraploid in terms of these two characteristics at quartet stage (Table 1;  $P \leq 0.01$ ,  $P \leq 0.01$ ). These results are in agreement with the findings reported earlier for the diploid and autotetraploid meadow fescue (21, 24, 27).

In diploid meadow fescue, the difference was statistically significant between the phosphate treatments in terms of regular tetrads and M/Q (Table 2;  $P \leq 0.01$ ,  $P \leq 0.01$ ). It is possible to note that the frequency of regular tetrads at that stage of meiosis was primarily determined by the genotypic control. It appears, however, that the phosphate treatments also influenced the regularity of tetrad stage. According to this result, the frequency of regular tetrad was lower in the control treatment than that of all other treatments whereas the number of micronuclei per tetrad was higher in the former than those of the latter (Table 2). On the other hand, it is reported that if the plants were exposed to nitrogen starvation for a longer period of time, meiotic

irregularities might have become more pronounced in autotetraploid rye (8).

In eutetraploid meadow fescue, the difference was statistically significant between the phosphate treatments for the frequency of regular tetrads (Table 3;  $P \leq 0.05$ ; Fig 4 a) whereas the difference was not significant between the treatments for the M/Q (Table 3; Fig. 4 b). However, the frequency of regular tetrads was found to be lower in the control treatment than those of all other treatments while the M/Q was higher in the former than those of the latter (Table 3). The situation was thus the same as that found in autotetraploid rye (8). In addition to genetic components there are also environmental factors influencing the quantitative expression of meiotic characteristics reported by some researchers (7, 9, 10, 11, 14, 15) and it is also shown that interaction occurs between the genetic and environmental determinants of chromosome behaviour in wheat (28).

#### Relationships Between Cytological Characteristics at Different Stages of Meiotic Division

In diploids, negative and significant associations were found between frequency of cells with balanced groups and the frequencies of all types of irregular AI segregations, as expected, the coefficients of correlation being highly significant in two cases of them (Table 4). On the other hand, there was positive and significant correlation between the frequency of AI cells with normal chromosome groups and the percentage of regular tetrads but there was negative and highly significant relationship between the former and the M/Q (Table 4). The magnitude of the coefficients of correlations ( $r=0.556$ ,  $r=-0.733$ ), indicate that AI cells with balanced groups produce regular tetrad cells at that stage. On the contrary, the remaining AI cells cause irregular tetrad cells, namely with micronuclei. Again, there was negative

and significant correlation between the frequency of cells with lagging univalents and the percentage of regular tetrads whereas positive and highly significant correlation was found between the former and the M/Q (Table 4). These results are in agreement with the hypothesis that the micronuclei result from the loss of daughter univalents of the longitudinally dividing anaphase I laggards (6). Some earlier researchers (5, 6, 25, 26) stated that similar relationships were found between cytological characteristics at different stages of meiotic division.

In induced eutetraploid meadow fescue, the frequency of AI cells with balanced groups was, as expected, negatively correlated with the frequencies of all types of irregular AI distributions, the coefficients of correlation being significant in three cases of them (Table 5). On the other hand, the frequency of balanced AI cells was positively associated with the percentage of regular tetrads and negatively correlated with M/Q, the coefficients of correlation, being highly significant in two cases (Table 5). Again, there was positive and significant correlation between M/Q and the frequency of AI cells with one or two lagging univalents (Table 5) whereas negative and significant association was found between the last two properties and the frequency of regular tetrads (Table 5;  $P < 0.05$ ,  $P < 0.05$ ). The expected increase in the percentage of regular tetrads parallel with the decrease in the frequency of AI cells with laggards was obvious while the increase in M/Q with decreasing the frequency of balanced AI cells was ascertained. This situation is in agreement with the results reported previously that the lagging univalents at AI were the most important reason for micronuclei in tetrads (6, 25, 26, 27, 29).

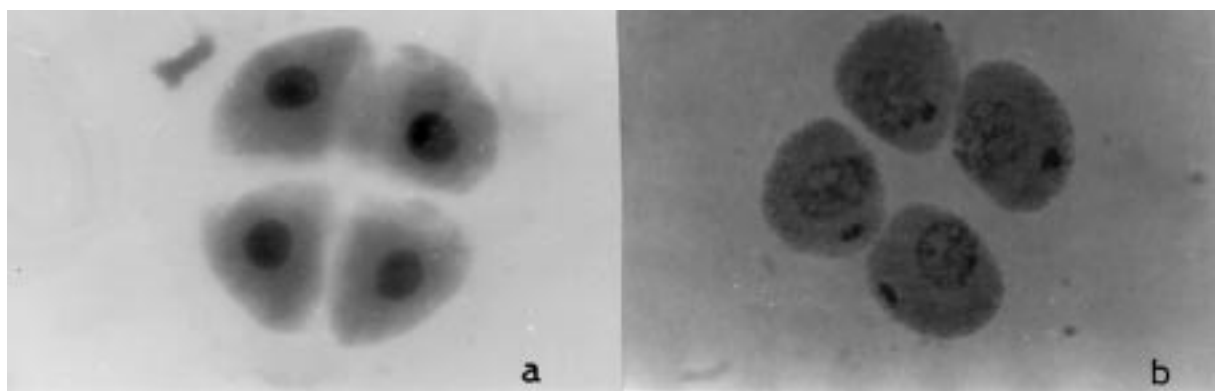


Figure 4. Regular tetrad without micronuclei (a), tetrad with micronuclei (b) in the pollen mother cells of eutetraploid meadow fescue (Enl.:1000 x)

Correlations	n	r	P≤
Frequency of PMC's with balanced segreg. at AI with:			
frequency of PMC's with lag. univ. at AI	20	-0.734	0.01
frequency of PMC's with lag. and divided univ. at AI	20	-0.459	0.05
frequency of PMC's with lag. chromatids at AI	20	-0.560	0.05
frequency of PMC's with lag. univ. and chr. brid. at AI	20	-0.625	0.01
frequency of PMC's with chromatid bridges at AI	20	-0.459	0.05
number of micronuclei per tetrad (M/Q)	20	-0.733	0.01
percentage of regular tetrads	20	0.556	0.01
Frequency of PMC's with lag. univ. at AI with:			
frequency of PMC's with chromatid bridge at AI	20	0.313	N.S.
frequency of PMC's with lag. and div. univ. at AI	20	0.313	N.S.
Frequency of PMC's with lag. chromatids at AI with:			
frequency of PMC's with chromatid bridge at AI	20	0.546	0.05
Frequency of PMC's with lag. univ. and chr. brid. at AI with:			
frequency of PMC's with lag. univalent at AI	20	0.419	N.S.
frequency of PMC's with lag. and divided univ. at AI	20	0.459	0.05
Number of micronuclei per tetrad (M/Q) with:			
frequency of PMC's with lag. univalent at AI	20	0.607	0.01
frequency of PMC's with lag. and div. univalent at AI	20	0.318	N.S.
frequency of PMC's with lag. univalent and chr. brid. at AI	20	0.448	0.05
frequency of PMC's with chromatid bridge at AI	20	0.318	N.S.
percentage of regular tetrads	20	-0.861	0.01
Percentage of regular tetrads with:			
frequency of PMC's with lag. univ. at AI	20	-0.490	0.05
frequency of PMC's with lag. univ. and chr. brid. at AI	20	-0.368	N.S.
frequency of PMC's with chromatid bridge at AI	20	-0.281	N.S.

Table 4. Coefficients of Correlation Between Some Cytological Characteristics at Meiosis Division in Diploid Meadow Fescue.

Correlations	n	r	P≤
Frequency of PMC's with balanced segreg. at AI with:			
frequency of PMC's with lag. univ. at AI	20	-0.832	0.01
frequency of PMC's with unbalanced seg. at AI	20	-0.370	N.S.
frequency of PMC's with lag. chromatids at AI	20	-0.462	0.05
frequency of PMC's with lag. univ. and chr. brid. AI	20	-0.386	N.S.
frequency of PMC's with chromatid bridge at AI	20	-0.454	0.05
number of micronuclei per tetrad (M/Q)	20	-0.857	0.01
percentage of regular tetrads	20	0.656	0.01
Frequency of PMC's with one lag. univ. at AI with:			
frequency of PMC's with chromatid bridge at AI	20	0.577	0.01
frequency of PMC's with lag. chromatids at AI	20	0.467	0.05
Frequency of PMC's with lag. chromatids at AI with:			
frequency of PMC's with chromatid bridge at AI	20	0.577	0.01
number of micronuclei per tetrad (M/Q)	20	0.313	N.S.
Frequency of PMC's with lag. univ. and chr. brid. at AI with:			
frequency of PMC's with two lag. univalents at AI	20	0.406	N.S.
Number of micronuclei per tetrad (M/Q) with:			
frequency of PMC's with one lag. univalent at AI	20	0.813	0.01
frequency of PMC's with two lag. univalent at AI	20	0.463	0.05
frequency of PMC's with two lag. univalent and chr. brid. at AI	20	0.429	N.S.
frequency of PMC's with chromatid bridge at AI	20	0.383	N.S.
percentage of regular tetrads	20	-0.833	0.01
Percentage of regular tetrads with:			
frequency of PMC's with one lag. univ. at AI	20	-0.547	0.05
frequency of PMC's with two lag. univ. at AI	20	-0.473	0.05
frequency of PMC's with lag. univ. and chr. brid. at AI	20	-0.305	N.S.
frequency of PMC's with chromatid bridge at AI	20	-0.301	N.S.
frequency of PMC's with unbalanced seg. at AI	20	-0.326	N.S.

Table 5. Coefficients of Correlation Between Some Cytological Characteristics at Meiosis Division in Eutetraploid Meadow Fescue.

## Conclusion

Anaphase I disjunctions were generally balanced in eutetraploids but the frequency of cells with normal chromosome groups was found to be lower than those of diploids. Similar results were found in terms of the percentage of regular tetrads in two ploidy levels. Accordingly, there were significant differences in terms of these two meiotic characteristics between diploid and eutetraploid plants (Table 1). On the other hand, the results showed no significant effect on the frequencies of different AI segregations due to different phosphate treatments at both ploidy levels. However, it was important to report that the lowest mean frequency of balanced AI segregation was obtained in the control treatment (Tables 2, 3). Again, the frequency of balanced segregation was higher in this advanced generation of autotetraploid population than  $C_3$  and especially  $C_0$  generations (21, 24). It was clearly seen that this meiotic improvement was realised in AI with an increase in the frequency of balanced segregation in spite of the decrease in the frequencies of all irregular AI segregations.

The result showed a significant effect on the percentage of regular tetrads under phosphate

treatments at two ploidy levels (Tables 2, 3). On the other hand, there was positive and significant relation between the frequency of balanced chromosome distribution and the percentage of regular tetrads in diploids and eutetraploids (Tables 4, 5). In the light of the evidence provided by studies on the characteristics of the two meiotic stages of diploids and eutetraploids, it could be said that the regularities or irregularities seen in meiotic divisions were interrelated. Based on this, in addition to balanced AI segregations, constituting a good criterion in determining the meiotic regularity and stability, very easily examined tetrads would also be of much use. This criterion was used in earlier studies and similar relationships were found by many other researchers who studied on various crop species (6, 25, 26, 27, 29, 30). Consequently, it is worth noting that an increase in the phosphate available to the plant is accompanied by an increase in the mean frequency of balanced AI cells in diploid and eutetraploids. Deciding about the meiotic regularity and stability could be easier when the percentage of regular tetrads as well as with balanced AI distributions are taken into account.

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