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Investigations on the Effect of Genes Controlling Response to Vernalization on Adaptation of Common Wheat (*Triticum aestivum* L.)

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ABSTRACT

Wheat is a very strategic product because it concerns to large communities. The only way to increase the required product is to increase the yield from the unit area. Spring wheat is sown in coastal ecology starting from Samsun and extending to Marmara, Aegean, Mediterranean, Çukurova and Southeast Regions to Diyarbakır and Şanlıurfa. Despite the genetically superior yields of spring wheats planted in these coastal areas, which have large and important ecological zones, there are adaptation problems. They suffer from the cold in winter. This prevents the high yielding varieties to achieve their potential yields. Moreover, in the coastal zone, spring wheats are damaged in late spring frosts due to their early heading. Even low temperatures in the flowering period cause flower infertility. Genes that control the response to vernalization play an important role in the adaptation of wheat as these not only ensures the adaptation of the wheat to the environment in early growth stages but also affects the heading dates. In this study, where winter and spring isogenic lines and their parents and some standard varieties were investigated in 22 coastal environments for grain yield, straw yield, biological yield, harvest index, hectolitre weight, thousand grain weight, plant height, days to heading, days to physiological maturity, grain filling period and protein content. Thirty genotypes of bread wheat (common wheat) varieties developed by CIMMYT and utilized commercially in many countries of the world, isogenic lines bearing their spring and winter vernalization genes (*Vrn-vrn*) and some standard bread wheat varieties were used in the research. Anza sibs show good adaptation to all environments, the superiority of winter isolines in the spring wheat ecology in terms of grain, straw and biological yield characteristics and the earlier heading of spring isolines are remarkable results of this investigation.

Keywords**:** Common wheat, *Triticum aestivum* L., vernalization, isolines, grain yield, yield related traits.

Introduction

Wheat is a very important product for all countries of the world and takes priority in feeding the rapidly growing world population. It is the major source of energy, protein and fibre in human diet (Arya *et al.* 2012, Preeti *et al.* 2016). One of the world's most wheat consuming countries is Turkey. It is a highly strategic product because annual production and consumption amounts are of importance that can affect the national economy, as well as for very large communities, including its producers.

Wheat is produced in about one-third of Turkey's workable farm-land. Although, production varies from year to year, it is estimated that it has changed between 17-22 million tons in recent years. It is not possible to increase the sown area for more products, even substitution of other crops and so on. The only way to increase the required product is to increase the efficiency taken from the unit area or at least not to decrease the product ceiling reached.

Winter and alternative wheats are produced in most of the cultivation areas. The coastal ecology starting from Samsun and extending to the Marmara, Aegean, Mediterranean, Çukurova and Southeast Regions to Diyarbakır and Şanlıurfa includes spring wheats. Although, the winter season in the coastal zones is

generally not severe enough to kill spring habitus wheats, it is able to meet the vernalization needs of all types of wheat, including winter and alternative types. It is frequently observed that winter habit types are more low-temperature tolerant than spring habit types (Limin and Fowler 2006). Despite the genetically superior yields of spring wheat planted in this coastal belt, which has large and important zones, there are adaptation problems. Generally, when wheat is planted early in these regions, it is damaged by the cold of winter as the plants develop rapidly due to the warm weather. However, the plant does not die due to the fact that this process is at the beginning of the development phase and the growth cone is close to the soil. Although, the negative effects of cold damage are not felt much due to regeneration in advanced stage, this situation prevents high yielding varieties from reaching their potential yields. On the other hand, in the coastal belt, especially the spring wheat of CIMMYT (1997) origin, early spike due to reach the stage of late spring frosts will be irreparably degree damaged to the extent that they cannot be recovered. Even low temperatures in the flowering period cause flower infertility. Although, the yield potential of spring wheat sown in the coastal belt is generally 8000-10000 kg/ha, the average of the region varies between 2500-3000 kg/ha. Various agricultural systems (cultivation technique applications) have an effect on this as well as the environmental incompatibility of genotypes. This mismatch, which causes fluctuations in production, is attributed to the damage from the cold in the growth cycle. In addition, early sowing is risky because late planting is preferred in the case, due to the short vegetation period; grain yield as well as biological yield is affected so that, genotypes performance is not possible to the desired level. In general, cereal plants have four ways of increasing the length of the vegetative phase, all of which extend the time that low-temperature tolerance genes are more highly expressed: (i) vernalization; (ii) photoperiod responses; (iii) increased leaf number; and (iv) increased length of the phyllochron [(interval between the appearance of successive leaves) (Limin and Fowler, 2002)]. Genes that control the response to vernalization play an important role in the adaptation of wheat as it not only ensures the adaptation of the wheat to the environment in early growth stages but also affects the time of heading. This hypothesis was supported by Davoud *et al.* (2015) as "vernalization responses regulate phenological growth and affect cold tolerance through influence on the rate of plant development." There are different features in the adaptation of plants to the environment. Heading or flowering in bread wheats are the most important characteristics of adaptation to the environment. Heading is determined by three factors: (i) vernalization request (response to vernalization), (ii) day length (photoperiod), and (iii) temperature (Yasuda and Shimoyama 1965). Their regulation of heading by combining them separately, with each other or with other factors, enables the distribution and adaptation of wheat to very large areas. Among these factors, many investigators have been based on the response to vernalization.

In general, winter types are considered to be the ancestors of springs. Aamodt (1923) reported that it is a general belief that winter forms are more ancient and more primitive.

The way to increase the yield in spring and winter wheats is to know the vernalization process well. Genes that respond to vernalization are identified by their growth property (growth nature). Flood and Halloran (1982), the property of being a little or no response to vernalization as a spring, described as a strong reaction as winter. In fact, this classification is both very sharp and very broad. Disintegration is also possible between these two extremes. Pugsley (1983), the concept of spring and winter based on the responses to the application of vernalization in bread wheat has brought a description based on genotype rather than phenotype. (*i*) *Vrn1* major gene wheats; This class which was unresponsive to vernalization was called "genetically spring wheat". (*ii*) Wheats carrying the *Vrn2, Vrn3, Vrn4* gene or combinations of these genes which are not *Vrn1* gene; also called semi-winter "genetically semi-winter=facultative wheat" (*iii*) Recessive alleles *(Vrn1, Vrn2, Vrn3* and *Vrn4),* which carry strong vernalization of wheat with the desire to "genetically winter wheat" is classified as (Molina 1985).

There has been no comprehensive and solution-oriented study on genes that react to vernalization in Turkey's coastal zones. The preponderance of genotypes carrying the recessive vernalization gene (*Vrn)* has been reported by many researchers in many countries whose ecology meets Mediterranean climate conditions. Molina (1985), in the Central California Valley, early sown winter wheat is very unlikely to suffer from late frosts at the time of heading, indicating that photoperiod insensitive winter wheat reduces the risk of product loss and benefit from this simple inheritance, reported that it would be an advantage even in a normal year when there is no frost at the time of the spike winter isolines according to springs 11% of yield superiority. If the genes controlling the response to vernalization lead to higher yield and improvement of other agronomic characteristics related to yield, the guided and consciously use of winter x spring crosses is an important consideration for the bread wheat programs in Turkey.

Materials and Methods

Genotypes

Genotypes used in the experiment; Bread wheat (*Triticum aestivum* L) varieties developed by CIMMYT (1997) and planted commercially in many countries of the world consist of isogenic lines carrying their spring and winter vernalization genes (*Vrn-vrn*) and some standard bread wheat varieties. Information on these genotypes is given in Table 1.

In the isogenic lines used in the study, a photoperiod insensitive winter wheat variety (Phoenix) and relatively photoperiod insensitive six spring wheat varieties (Anza, Yecora Rojo, Tanori 71, Portola, Siete Cerros 66, and Pitic 62) were used (Molina 1985). The isogenic lines were obtained by backcrossing three to five times and single plant selection was performed by pedigree method after each crossing.

The trial included isolines and their parents, as well as Anza-W, Anza-S, Yecora Blanco-W, Tanori-W, Tanori-S and Pitic-W, which have white-grained, close lines with both winter and spring nature. Yolo, a type of spring bread wheat developed at the University of California and Seri 82, Cumhuriyet 75, Ata 81, and Kaklıç 88 Turkish spring bread wheat varieties, which have large sowing areas in Turkey's coastal belt, especially in Çukurova and Aegean Regions, were also added as standards to the experiment.

Experimental locations

Carried out in three different locations of Aegean Region in 1991-1992 was established in the first year of the experiment in Menemen-İzmir, Milas-Muğla and Sarayköy-Denizli. In the 1992-93 season; In addition to these three trials, the application was carried out in 10 locations: Merkez-Balıkesir, Merkez-Çanakkale, Adapazarı-Sakarya, Merkez-Samsun, Merkez-Diyarbakır, Akçakale-Şanlıurfa and Yüreğir-Adana. In the third year (1993-94), Aksu-Antalya location was added along with İzmir, Denizli, Balıkesir, Sakarya, Samsun, Diyarbakır, Şanlıurfa and Adana. When the year and locations were accepted as an environment, the research was carried out in a total of 22 environments (Table 2).

In this research, the "Coastal Belt" in another words "Spring Wheat Ecology" which starts from Samsun and extends to Marmara, Aegean, Mediterranean and Southeast Regions, to Diyarbakır and Şanlıurfa provinces. In the coastal belt, the winter season is strong enough not to kill spring wheat and has the advantage of meeting the need for vernalization all types of wheat, including winter and alternative (facultative) types.

Field trials management

The experiments were conducted in randomized block design with four replications. The plots were planted in 6 rows 5 m length and the distance between the rows was 20 cm. The amount of seed used was determined to be 500 seeds/m^2, depending on the weight of 1000 seeds of each variety. Planting was carried out with trial seeder in a timely manner with no gap between the parcels. The harvest was carried out in an area of 3.6 m^2 (4 rows x 4.5 m x 0.20 m) by removing 2 edge rows of 6 m^2 parcels and 25 cm from the both heads.

In the fields where the trials were established, care was taken to ensure that there were plants that will not adversely affect wheat as a preliminary plant. Before planting, soil tillage, seed bed preparation, fertilization, post-emergence maintenance works were conducted according to the research findings in the region where the experiment was performed. For example; optimum fertilizer doses of the region were applied by taking soil analysis reports into account.

Necessary measures have been taken where bird damage can be significant; weed growth was not allowed and chemicals were used when necessary. However, no chemicals were used and weed control was done manually because it might affect the heading dates in Menemen location. Although, all fertilizers of (P) and (K) were applied together with planting, fertilizer N was applied twice in planting and spring. The research findings of the region were also taken into consideration in terms of fertilizer type and application times.

The harvest was made with parcel harvesters, and the table of the harvester was completely lowered to the soil surface to measure the biological yield of the parcel, and special sacks were installed on the back of the harvester to collect the harvested straw.

Application differences in some of the experiments carried out in a total of 22 environments over years and location (such as mowing and mowing with a parcel threshing machine) are not mentioned as they do not affect the result of the experiment.

Scored traits

Grain yield (kg/ha), straw yield (kg/ha), biological yield (kg/ha), harvest index (%), hectoliter weight (kg), thousands kernel weight (g), plant height (cm), heading date (days), maturity date (days), grain filling period (days) and protein content (%) (Uluoz 1965; Tecator manual 1979) were scored.

Statistical Analysis

Analysis of variance was performed according to the models proposed by Steel and Torrie (1960), Rusmusson and Lambert (1961) and Snedecor and Cochran (1960). The methods developed by Comstock and Moll (1963) were used to determine the variance components in the agronomic characteristics studied.

Four different linear models have been considered for the determination of variance components (Gordon *et al.* 1973; Mead, 1988):

Model 1: Describes single-site and single-year trials.

Model 2: Linear mathematical model for experiments conducted in more than one site in a year.

Model 3: Linear mathematical model for experiments conducted in the same site in multiple years.

Model 4: Linear mathematical model applicable to experiments conducted in different sites and years.

Test of ordered means: Although, the F test was not statistically significant, the differences were checked at 0.05 significance with the LSD (Least Significant Difference) test, since the comparison of the ordered means for the characteristics of genotypes was one of the purposes of the study (Steel and Torrie 1960).

Test of grouped means: The average of six winter isogenic lines $\{W_{(IL)}\}$ and six spring isogenic lines $\{S_{(IL)}\}$ obtained from six springs and one winter parent were calculated from the linear function of the averages described by Steel and Torrie (1960).

The calculations were made using the MSTAT-C package program at the Aegean Agricultural Research Institute in Izmir.

Results and Discussion

The most important goal of this study was to examine the adaptation of the isogenic lines of vernalization. The interaction of the agronomic characteristics of the genotypes with the environment is of great importance. In this respect, the 11 agronomical characteristics were examined in four different models.

Grain yield

According to the results of variance analysis obtained in single location and single year in Antalya in 1992-1993 cultivation season in Canakkale in 1993-94 cultivation season, significant differences were found between genotypes (p=0.001). While the average yield in Çanakkale ranged from 4174 to 6622 kg/ha, these limits were lower (2160-4611 kg/ha) in the Antalya location. The average location in Canakkale was 5909 kg/ha and the average location in Antalya was 3142 kg/ha. In the comparison of six winter $\{W_{(IL)}\}$ and six spring $\{S_{(IL)}\}$ isolines, there was no statistically significant difference between both Çanakkale and Antalya locations. However, yield differences were in favor of spring isolines (Çanakkale $\bar{y}_w$= 5655 - $\bar{y}s$= 5745 = -90^{ns} kg/ha; Antalya $\bar{y}w$ = 2805 - $\bar{y}s$ = 2870 = -65^{ns} kg/ha). In the combined analysis of variance of İzmir, Denizli and Muğla locations according to the single year and multi-site model, the variation between genotypes was found to be very high in both 1991-92 and 1992-93 sowing years (p=0.001). Location averages for years are given as kg/ha in Table 3.

Grain yield of İzmir, Denizli, Muğla and Şanlıurfa locations according to single location and multiyear model, year variations varied according to locations. Although, the variation between years in Denizli location was statistically nonsignificant, it was very high in İzmir location (p=0.001) and high in Muğla location (p=0.01). In the Şanlıurfa location, the year variance was significant at 0.05 level. The difference between genotypes was very high in all four locations. Genotype x year interactions were important for all four locations. Grain yield of the locations in different years in the general average was given in Table 4.

The combined grain yield averages over the years were 5318-6793; 6031-7500 in Denizli; 4605-6571 in Muğla and 4142-6188 kg/ha in the province of Şanlıurfa.

Grain yields obtained from seven locations for two years in the analysis of combined data according to multi-site and multi-year model; In addition to the main sources of variation such as year, location, genotype, all binary and triple interactions were also very important. The combined year and location averages of grain yields ranged between 4549-5725 kg/ha.

The average (kg/ha) of the seven locations analyzed according to the combined grain yield data for two years is given in Table 5.

The comparison of the six winter $\{W_{(IL)}\}$ and six spring lines $\{S_{(IL)}\}$ from the isogenic lines obtained by back crossing in the six spring and the one winter parent was significant at the level of p=0.001 between spring and winter. In the comparison where one isoline from each cross was taken into consideration, the average winter grain yield ($\bar{y}w$) was 5234 kg /ha, while that of spring isoline ($\bar{y}s$) was 5041 kg/ha and the difference of the mean ($\bar{y}w$-$\bar{y}s$) was 193 kg per hectare combined genotype averages over 7 locations and 2 years for grain yield (kg/ha). The genotypes belonging to the first group of the averages listed in the analysis are given in Table 6.

When the results of the experiments are analyzed in separate locations, over years, combined data over locations and years; genotypes other than standard varieties in terms of grain yield; Anza-S, Anza-W, Anza-S, Anza-W, Anza, Phoenix, YecoraRojo-W, Yecora Blanco-W, Tanori-W, Tanori-W, Tanori -S, Pitic-S, Pitic-W, Pitic-W, Siete Cerros-S and Yolo were prominent genotypes. On the other hand, Turkey's spring wheat ecology in coastal areas-especially in the Aegean Region-largely from local standard varieties in cultivation which finds Kaklıç88 and Seri 82 are all the

trials came to the fore in terms of grain yield. Ata 81 also included in these two varieties in many locations. For Cumhuriyet 75, average grain yield was obtained at the locations. In the grain yield analysis of varieties and lines, it is note worthy that Anza variety and all sibs (Anza-S, Anza-W, Anza-S and Anza-W) were at the fore front in almost all locations. Seri 82, Kaklıç 88 and Ata 81, which are standard varieties, competed with Anza sibs in many locations. Anza is a variety registered in the US State of California and later in Australia, similar to WW15, with a winter genotype in its pedigree. It is widely used in crossing programs in the USA, Mexico, South Africa, Australia and many other countries and is known to have good adaptability (Molina 1985; CIMMYT 1997). In Western Australia and particularly California, Mediterranean climate of ongoing and climate shows great similarities with Turkey's spring wheat ecology. On the other hand, Seri 82 and Kaklıç 88 come from the same hybrid and are sister lines. Seri 82, Kaklıç 88 and Ata 81 have winter variety Kavkaz blood. The fact that breeding lines and varieties with a winter base in pedigree came to the fore both confirms the purpose of this research and confirms Pugsley's (1983) claim.

In combined analyzes over locations that allow genotype x location interaction, genotype x location interaction was statistically significant at p=0.001 in both 1991-92 and 1992-93. Likewise, it allows the calculation of genotype x year interaction; In the analysis of the combined data of İzmir, Denizli, Muğla and Şanlıurfa locations over different years, genotype x year interactions were very important in statistical terms. Allowing three-way interaction; seven locations and locations of two years and in the combined analysis over the years, both genotype x location, genotype x year and triple interaction genotype x year x location p=0.001 levels were found to be non-zero**.** This shows that double and triple interactions are highly effective on grain yield. This emphasizes that these locations for the grain yield in bread wheat trials requires that the trials be performed in more than one location and year. Baker (1969) and Ikiz (1976) on spring bread wheats, Gill *et al.* (1984), Sabancı (1991) on common vetch, Öztan (1992) and Attary (1993) reached similar results in studies on wheat and triticale.

A significant difference was found between winter and spring isolines for grain yield at the level of p=0.001. Winter isolines $\{W_{(IL)}\}$ yielded an average of 193 kg per hectare than spring isolines $\{S_{(IL)}\}$. In the case of 11 locations where spring wheat ecology is studied in terms of plant genetic resources, the fact that many of the village populations or varieties specific to these regions are facultative and even winter type confirm that these results are expected results. Since no research has been found with vernalization isogenic lines in spring wheat ecology in Turkey, it is not possible to compare the results of the research with others. However, the results are consistent with the findings that the researchers conducted in the State of California, USA, using the same isogenic lines, yields a yield advantage of 11% compared to spring isolines (Molina 1985). Whereas in Romania on average, spring isolines over-yielded the winter ones by over 400 kg/ha at the normal planting date and by about 160 kg/ha at late planting, and also a significant correlation ($r=0.80^{*}$) was found between the effect of *Vrn* alleles on heading date and the effect on grain yield (Mustatetea *et al.* 2011).

For two years (1992-93 and 1993-94), in the analysis of the combined data of the seven locations over the years and locations, it was determined that the Aegean Region locations out performed the other coastal area locations in terms of grain yield. The significance of the differences between 1991-92, 1992-93 and 1993-94, in which the trial was applied, varied according to locations. While, the differences between years in İzmir, Muğla and Şanlıurfa locations were significant at p=0.05 level, there was no difference between years in Denizli location. The result obtained in Denizli location can be attributed to the cultivation technique and the effectiveness of irrigation.

The coefficients of variation determined in the analysis of the experiments in 22 different environments separately or combined according to various models over the years and locations where the research was applied were found to be non-hindering values for the evaluation of the experiments. The findings for grain yield are summarized as follows: (i) Genotypes were significantly different; (ii) Anza and sibs have attracted attention among other genotypes; (iii) Genotype x site, genotype x year and genotype x year x site interactions were highly effective in grain yield; (iv) Winter isolines showed yield superiority over spring isolines; (v) Aegean Region locations have yield superiority over other spring wheat ecology locations; (vi) Significant differences between the years were observed in the majority of locations; (vii) CV% values found to be appropriate to the extent that they do not interfere with the evaluation of trials.

Straw yield

In the analysis of the data obtained in sown year 1992-93 at the Çanakkale location, no significant variation was found among the genotypes in terms of straw yield. The average straw yields were between 5826-8042 kg/ha.

In the combined variance analysis for straw yield of İzmir, Denizli and Muğla locations; The genotype

x location interaction variance of the years 1991-92 and 1992-93 was non-significant for 1991-92 and highly significant for 1992-93. The combined genotype averages over the locations were found to be straw yields of 6750-9498 kg/ha; In the second year, it ranged between 6248-8755 kg/ha.

In the analysis of the combined data of İzmir, Denizli and Muğla locations separately over the years, the main variables for all three locations are; year and genotype variances were found to be very important in uniform level. Genotype x year interaction variances showed variability between locations, although, it was found to be significant with the probability of 0.01 in İzmir and Denizli, it was non-significant in Muğla.

Fitting in the variance analysis results obtained for straw yields of genotypes over multiple years and locations, although, the variance of genotype x year was significant at 0.05 level, the variances of all other variation sources including triple interaction were found to be significant at 0.001 level. Genotype average yields ranged from 6640 to 8618 kg/ha. According to the two-year data averages of straw yields (kg/ha) of the locations are given in Table 7.

The comparison of winter $\{W_{(IL)}\}$ and spring $\{S_{(IL)}\}$ isolines in terms of straw yield was significant at p=0.001. While the average of winter isolines ($\bar{y}w$) was 7830 kg/ha, the average of spring isolines ($\bar{y}s$) was measured as 7577 kg/ha and the difference between winter and spring ($\bar{y}w$-$\bar{y}s$) was calculated as 253 kg/ha.

Genotypes belonging to the first group of averages listed in the analysis of combined genotype averages over 7 locations and 2 years for straw yield (kg/ha) are given in Table 8.

The results obtained in 20 different environments in terms of straw yield are summarized as follows: (i) Genotypes were found to be significantly different; (ii) Anza and sibs and Siete Cerros sibs have attracted attention among other genotypes; (iii) Binary and triple genotype x environment interactions had an effect on straw yield; (iv) Winter isolines were more productive in terms of straw yield than the spring counterparts; (v) CV% values calculated in variance analysis showed that the data were healthy and safe in terms of straw yield.

Biological yield

In the analysis of the biological yield data obtained in the planting season of 1992-93 in the Çanakkale location, a very high level of variation was found among the genotypes. The distribution range of genotype averages was 11120-14170 kg/ha.

In the combined variance analysis of the 1991-92 data of İzmir, Denizli and Muğla locations; location, genotype and genotype x location interaction and genotype and genotype x location interaction variance of 1992-93 were found to be significant at p=0.001 level. In the combined analysis of these three locations in 1992-93, the variation between the locations was non-significant. The distribution range of the combined average of genotypes over İzmir, Denizli and Muğla locations was 13010-16190 kg/ha in 1991-92 and between 12110-15010 kg/ha in 1992-93. In the combined analysis, İzmir and Denizli data were calculated for 3 years and Muğla data for 2 years. Although, all of the year, genotype and genotype x year interaction variances of İzmir and Denizli locations were statistically significant, year and genotype x year interaction variances were non-significant except for the variation between genotypes in Muğla location. In Muğla location, a significant difference was found between the biological yields of genotypes at the level of 0.001. The combined biological yield values over the years and locations varied between 11.350-14.330 kg/ha.

When the results of combined variance analysis of biological yield data over 7 sites and 2 years were examined, it was seen that the variances of all variation sources such as year, location, year x location, genotype, genotype x year, genotype x location and genotype x year x location were found to be highly significant. In terms of biological yield, the average hectare yields of the seven locations in the analysis are given in Table 9.

The comparison of winter $\{W_{(IL)}\}$ with spring $\{S_{(IL)}\}$ isolines in 1 degree of freedom was statistically significant at p=0.001. The average of winter isolines is $\bar{y}w$ = 13063 kg/ha, the average of spring isolines was $\bar{y}s$= 12620 kg/ha and the difference between the average of winter and spring isolines is $\bar{y}w$ - $\bar{y}s$=443 kg/ha.

The biological yields of the genotypes included in the first group in the combined analysis of seven locations and two years are as shown in Table 10.

The findings for the biological yield feature are summarized; (i) Genotypes were significantly different; (ii) Anza and sibs, as well as the winter genotype Phoenix and the standard variety Ata 81 have been more productive genotypes; (iii) Genotype x environment interactions were effective for biological yield; (iv) Denizli location was determined as the most efficient location in biological yield as well as grain and straw yields; (v) Winter isolines were found to be more efficient than spring isolines; (vi) CV% values calculated in variance analysis showed the reliability of biological yield results.

Harvest index

According to the results of the variance analysis performed on the data obtained at the Çanakkale location during a growing season, there was a significant variation

among the genotypes in terms of harvest index. In Çanakkale, the distribution of harvest index of genotypes was found to be between 36.99-49.44%.

In the combined analysis of İzmir, Denizli and Muğla locations, both the location, genotype and genotype x location interactions were found to be highly significant in both 1991-92 and 1992-93. Distribution of genotypes over these three locations was 38.01-49.35% for 1991-92 and 41.27-51.10% for 1992-93.

According to the combined data of the locations one by one over three years, it is seen that the variations calculated for all variation sources in İzmir, Denizli and Muğla locations are highly important. In the combined data over the years, the distribution ranges were 36.02-46.86% for İzmir location; It was found to be 39.62-51.18% for Denizli and 36.21-47.62% for Muğla.

In the combined variance analysis over seven locatons and two years, the binary and triple interactions as well as all the main variables were found to be highly significant (p=0.001). The percentage of harvest indexes in the combined genotype averages of different locations and years ranged from 37.76 to 43.99.

Corresponding to data of multi-location and multi-year, the locations of the harvest index percentages are grouped in Table 11.

The comparison of winter $\{W_{(IL)}\}$ and spring $\{S_{(IL)}\}$ isolines showed no difference in harvest index. The percentages of winter and spring isolines as $\bar{y}w$=40.19 and $\bar{y}s$=40.06, and the non-significant difference of the means are $\bar{y}w$-$\bar{y}s$=0.13%.

In the combined analysis over seven locations and two years, the genotypes included in the first group of the averages were Seri 82 (43.99%) and Yecora Rojo-W (43.40%).

Summary results of harvest index feature; (i) Genotypes were significantly different; (ii) Yecora sibs, Seri 82 and Kaklıç 88, attracted attention among other genotypes; (iii) Binary and triple genotype environmental interactions appeared to be highly effective in harvest index; (iv) No statistical difference was observed between winter and spring isolines in terms of harvest index; (v) Adana location was identified as a region that promotes high harvest index; (vi) Low CV values indicate that harvest index data can be used safely

Hectoliter weight

Genotype variance was found to be highly significant in both variance analyzes (Çanakkale and Antalya) performed on one site and one year. The distribution ranges of the genotype averages were 69.78-79.25 kg in Çanakkale and 64.99-77.75 kg in Antalya.

In the analysis of variance based on locations in two separate years of the trials, both location and genotype and genotype x location interaction variances were found to be highly significant within two years. The combined genotype averages of İzmir, Denizli and Muğla locations were 68.71-78.48 kg in cultivation year 1991-92 and 73.73-81.91 kg in cultivation year 1992-93. Location, genotype and genotype x year interaction variances were found to be statistically significant in all three locations of İzmir, Muğla and Şanlıurfa. The genotype averages of the combined data over the years ranged between 72.53-80.88 kg at İzmir location; 66.85-78.20 kg at Muğla location; 74.39-81.22 kg at Şanlıurfa location.

In the variance analyzes performed by combining two trial years and 6 locations for hectolitre weight, all interaction variances were found to be very important as well as location, year and genotype variances. The means (kg) and LSD tests of the combined locations are as shown in Table 12.

There was no statistically significant difference between winter $\{W_{(IL)}\}$ and spring $\{S_{(IL)}\}$ isolines in terms of hectolitre characteristics. The mean values of isolines were $\bar{y}w$=74.73 kg and $\bar{y}s$=74.88 kg. The genotype Tanori-W was with 77.74 kg, which was statistically in the top group according to the combined results of the six locations, two years, over locations and years.

In summary: (i) Variation between genotypes was found to be highly significant for the weight of the hectoliter; (ii) Tanori and Portola sibs have received more attention than other genotypes; (iii) Genotype x environment interactions were effective and significant for hectolitre weight; (iv) No difference was observed between winter isolines and spring isolines; (v) Balıkesir and İzmir locations were found to promote hectoliter weight compared to other locations; (vi) Uniformly low CV values calculated in the analysis results showed the liability of the data.

Thousand grain weight

Data obtained from Çanakkale and Antalya locations showed that the variation between genotypes was very important and the average weight of the genotypes ranged from 28.22-45.01 g in Çanakkale and 23.63-43.85 g in Antalya.

The variance between location and genotypes was very important in the combined analysis over İzmir, Denizli and Muğla locations, genotype x location interaction variance showed great variability between years, but it was found significant at p=0.001 level in 1992-93 cultivation year, whereas, it was non-significant in 1991-92 cultivation year.

Agreeing with the combined data of the three locations, the distribution ranges of the average thousand grain weights of the genotypes did not deviate much compared to the years. In 1991-92 the dispersal ranges were 30.41-51.11 g in 1992-93 years 34.17-51.98 g. Checking out the analysis of combined data over three years in İzmir location and two years in Muğla and Şanlıurfa locations, the variance of all sources was significant at p=0.001 for thousand grain weight. For Izmir, Muğla and Şanlıurfa, the ranges of thousand grain weight changes combined over the years were 29.35-47.94 g; 26.20-45.23 g and 34.31-48.15 g respectively. According to the combined data of multi-site and multi-year genotype averages, the distribution ranges are 28.50-45.80 g.

As it can be seen in the combined variance analysis over six locations and two years, the variances of year, location, year x location, genotype, genotype x year, genotype x location and genotype x year x location interaction were very important. Based on the analysis of the combined data over the year and location, the six locations were listed in terms of thousand grain weights as in Table 13.

Winter $\{W_{(IL)}\}$ and spring $\{S_{(IL)}\}$ isolines were statistically different at p=0.001. Corresponding to the results of six locations and the combined data of two years, the average weight of the winter isolines is $\bar{y}w$ = 34.77 g and the average weight of the spring isolines $\bar{y}s$ = 35.82 g. The difference was 1.05 g and it was found in favor of the springs. Agreeing with the combined averages over years and locations, the largest grain genotype is Cumhuriyet 75 and a thousand grain weight was 45.8. After Cumhuriyet 75, the highest thousand-weighted genotype was Tanori-W with 40.85 g.

The findings for a thousand grain weight are summarized as follows: (i) Significant variation was observed between genotypes; (ii) Cumhuriyet 75 differs from the others in this feature. After Cumhuriyet 75, Tanori and Yecora sibs became prominent genotypes; (iii) Genotype x environment interactions were found to be significantly effective on thousand grain weight; (iv) Thousand grain weights of spring isolines were found to be better than their counterparts the winters; (v) Sakarya has been identified as the best location for a thousand grain weight; (vi) The CV values determined in all trials were calculated around the expected values from a sensitive trial.

Plant height

Check out the results of variance analysis obtained from one location and one year, significant differences were found between genotypes in terms of plant height in one-year trials conducted in Çanakkale during the 1992-93 sowing season and in Antalya during the sowing season of 1993-94. While the average height of genotypes in Çanakkale ranged from 55.65 to 90.70 cm, these limits were higher 88.75-130.30 cm in Antalya.

In the single-year, multi-site model of variance analysis of İzmir, Denizli and Muğla sites; location, genotype and genotype x location interaction variances were found to be significant in both of 1991-92 and 1992-93 sowing years.

In 1991-92, the combined average plant height limits of İzmir, Denizli and Muğla locations decreased to 59.67-99.67 cm.

Agreeing with the single-site and multi-year model of İzmir, Denizli, Muğla and Şanlıurfa locations, in the combined variance analyzes for plant height, over 3 years in İzmir and Denizli and 2 years for Muğla and Şanlıurfa; only in İzmir and Şanlıurfa locations, year variance was found to be 0.05, and in all other locations all variables and interaction variances were found to be significant at 0.001.

Distribution ranges of genotype averages according to combined data over the years in Izmir, Denizli, Muğla and Şanlıurfa has been 68.62-108.90; 66.38-105.40; 63.22-99.53 and 65.18-99.61 cm, respectively.

In the analysis of the data obtained from seven locations for two years; In addition to the main sources of variation such as year, location, genotype, all binary and triple interactions were also very important.

The average of plant heights combined over two years and seven locations ranged between 68.36-105.70 cm.

The average of the seven locations analyzed according to the combined plant height data over years and locations are given in Table 14 in cm.

No statistically significant difference was observed between winter $\{W_{(IL)}\}$ and spring $\{S_{(IL)}\}$ isolines in terms of plant height characteristics. The average heights of isolines in cm is $\bar{y}w$=92.05 and $\bar{y}s$=91.20. Agreeing with the combined data over seven locations and two years for plant height feature; The highest winter isoline Tanori-W: 105.7 cm; the highest spring isoline is Ciete Cerros-S: 101.3 cm; the shortest winter isoline Yecora Blanco-W: 68.36 cm; The shortest spring isoline is Yecora Rojo-S: 72.36 cm.

The results obtained for plant height are summarized as follows: (i) Genotypes were found to be significantly different. (ii) The highest genotype was Tanori-W and the shortest genotype was Yecora Blanco-W; (iii) Seri 82 and Kaklıç 88 with Anza sibs, yield type genotypes; It was determined to be of medium height around 90 cm; (iv) Genotype x environment interactions were highly effective for plant height; (v) No difference in height between winter and

spring isolines; (vi) Sakarya has been identified as an encouraging location for plant height; (vii) Uniformly low CV values implied reliability of the data.

Heading date

Genotype variance was found to be statistically significant in all analyzes performed in one location and one year in Antalya, Samsun and Diyarbakır locations. In the Antalya location, Tanori-S, Yecora Rojo-S, Portola, Portola-S, Tanori 71, Yecora Rojo and Tanori-S lines and varieties were found to be earlier than Cumhuriyet 75. Siete Cerros-W, Anza-W and Phoenix have been identified as the latest line and variety. The earliest genotypes in Samsun location; Tanori-W and Tanori-W; The latest genotypes are Siete Cerros-W, Siete Cerros 66, Yolo and Siete Cerros-S. The earliest genotype in Diyarbakır was Tanori-W, Tanori-S, Tanori 71, Tanori-S and Tanori-W, respectively. The latest genotypes in this location were Siete Cerros-W and Ata 81.

In the analysis of the combined data over three years in İzmir location; year, genotype and genotype x year interaction variances were found to be very important for the number of days to heading. According to the combined three year data, Tanori-S and Tanori 71 were the earliest genotypes and Siete Cerros-W as the latest genotypes.

In the three year average of the İzmir location, the number of heading days ranged from 102.3 to118.3, while the variety of Cumhuriyet 75 was found to be close to the general average with 110.1 days.

Checking out the results of combined variance analysis over the years, a significant difference was observed at the level of p=0.001 in the comparison of winter $\{W_{(IL)}\}$ and spring $\{S_{(IL)}\}$ isolines. The difference between the average of winter and spring isolines was 4.6 days, and the winters were determined as late. The average of winter isolines was calculated as $\bar{y}w$=112,9 days while the average of spring isoline was calculated as $\bar{y}s$=108.3 days. However, in the analysis of multi year combined data; Yecora Blanco-W, Yecora-W, Portola-W, Tanori-W and Tanori-W winter isolines appear to be earlier than the Seri 82 standard variety.

The findings obtained in terms of spike characteristics are summarized as follows: (i) Variation between genotypes was sufficient to allow selection of early or late varieties; (ii) Tanori-S and Tanori 71 were the earliest and Siete Cerros-W as the latest genotypes; (iii) Anza's winter isolines are identified as late in days to spike and spring isolines were defined as intermediate-early; (iv) Anza-S was average of one day later than Seri 82 in number of days to spike; (v) Winter isolines were later than spring isolines; (vi) Genotype x year interaction was found to be very effective on heading dates; (vii) CV values of 1% or less indicated the sensitivity of spike observations.

Number of days to physiological maturity

In the analysis of the combined data over three years in İzmir location, the variance between genotypes as well as year and genotype x year interaction variance were found statistically significant at the level of 0.001. In the combined analysis over the years, the average number of physiological maturity days of genotypes ranged from 146.9-155.2. In terms of physiological maturity, Tanori-S, Portola-S, Tanori 71, Yecora Rojo, Tanori-S, Portola were the earliest and Siete Cerros-W, Siete Cerros 66, Anza-W, Phoenix were identified as the latest genotypes. Standard variety Cumhuriyet 75; It was found to be close to the general average with the number of 152.2 days while the average of spring isoline was calculated as $\bar{y}s$=149.5 days.

Significant differences were observed between winter isolines $\{W_{(IL)}\}$ and spring $\{S_{(IL)}\}$ isolines at the level of p=0.001. Checking out the combined data over the years, it is concluded that spring isolines were 2.7 days earlier than the winters. The average of winter isolines was calculated as $\bar{y}w$=152.2 days and average of spring isolines $\bar{y}s$=149.5 days. On the other hand, Seri 82 and Cumhuriyet 75 standard varieties were found in the same group, but earlier winter isolines Tanori-W has reached to physiological maturity in 150.3 days and Cumhuriyet 75 and Seri 82 in 150.3 and 151 days, respectively.

The findings obtained in terms of the number of days to physiological maturity are summarized as follows: (i) The variation among the genotypes investigated was very high; (ii) The physiological maturity characteristic gave findings parallel to the spike characteristic; (iii) Tanori-S, Portola-S, Tanori 71, Yecora Rojo, Tanori-S and Portola were identified as the earliest genotypes; (iv) Siete Cerros-W, Siete Cerros 66, Anza-W and Phoenix were the latest genotypes; (v) Genotype x year interaction was found to be highly effective on physiological maturity; (vi) It was determined that winter isolines were later than the spring counter parts; (vii) Tanori-W winter isoline was observed to be approximately one day earlier than Seri 82; (viii) Very low CV values calculated in the trials were indicative of the sensitivity of the observations.

Grain filling period

Genotype and year variance and genotype x year interaction variance were significant at p=0.001 in the analysis of combined data over one location and three years in terms of grain filling period. The combined genotype averages over the years in İzmir location

vary between 36.42-44.58 days. Standard variety Cumhuriyet 75 was determined to be close to the general average with 40.08 days in terms of grain filling periods. Tanori-S, Tanori 71, Yecora Rojo, and Yecora Rojo-S are the genotypes with the longest days of grain filling period. Kaklıç 88, Ata 81 and Siete Cerros-W were the lines and varieties with the minimum number of days.

In the analysis of the combined İzmir location data over the years, a significant difference was found in the comparison of winter $\{W_{(IL)}$ and spring $\{S_{(IL)}\}$ isolines at p=0.001. It was determined that spring isolines had an additional grain filling period of 1.97 days. The average of $\bar{y}w$=39.29 days, while the average of $\bar{y}s$=41.46 days. However, winter isolines with the same period as standard varieties are available, as will be observed from the values obtained.

In summary, the results of the findings obtained for three consecutive years in İzmir location in term of grain filling period: (i) Genotypes were significantly different; (ii) In general, it was found that the early varieties had a long grain filling period and that the late varieties had short grain filling period; (iii) Tanori-S, Tanori 71, Yecora Rojo and Yecora Rojo-S have been identified as the longest genotypes; (iv) Siete Cerros-W, Kaklıç 88 and Ata 81 were found to have the shortest genotypes. (v) Genotype x year interaction had an effect on grain filling period; (vi) Grain filling period of spring isolines was longer than in the winter; (vii) The calculated low CV value implied that the observations were healthy.

Protein content

As it can be seen in the combined variance analysis over the locations of the 1992-93 sowing season data obtained from ten different locations, significant statistical differences in terms of protein content among genotypes as well as location and genotype x location interaction variances were found to be important. The combined genotype averages of the ten locations were distributed between 11.66%-14.97%. Portola-W, Yecora Rojo-S and Portala are the genotypes with the most protein content. Table 16 shows the classification of ten locations in terms of percentage of protein.

According to the combined data over the locations; Cumhuriyet 75 standard variety the average protein content of 13.73 was found close to the average of the experiment.

In the analysis of the combined trials over ten locations, spring isolines $\{S_{(IL)}\}$ were statistically different from winter isolines $\{W_{(IL)}\}$ p=0.001 in terms of protein content. Spring $\{W_{(IL)}\}$ isolines have 0.31% more grain protein than the winters, average of winter isolines $\bar{w}y$=13.21%; The average of spring isolines was $\bar{s}y$=13.52. On the other hand, winter isoline Portola-W, which is in the first group in the grouping of the combined data over the locations, was found to be the first with 14.97% protein content.

In the combined analysis over the locations, the findings for the percentage protein content in the grain are summarized as follows: (i) The genotypes were found to be different in protein content; (ii) Portola-W, Yecora Rojo-S and Portola were identified as genotypes with the highest protein content; (iii) From the protein analysis results, it was estimated that there was a negative relationship between grain yield and protein content; (iv) Genotype x site interaction was effective for protein content trait; (v) It is possible to combine more protein properties in spring isolines than in the winter; (vii) İzmir location is defined as the location to increase and promote protein percentage in the grain; (viii) The calculated low CV value indicated that the analyzes were performed correctly.

It was concluded that Anza sibs show good adaptation to all environments, the superiority of winter isolines in the spring wheat ecology in terms of grain, straw and biological yield characteristics and the earlier heading of spring isolines are remarkable results of this investigation.

In spring wheat ecology, it is strongly recommended to use spring x winter crosses. The point highlighted here is not entirely about the selection of winter material. The important thing is to transfer the winter base to hybrids. As a matter of fact, the performances of the Seri 82 and Kaklıç 88 varieties, which have a wide base for years in the coastal belt and have a winter base, and the fact that the village varieties (landraces) in the coastal belt and the material of the collected genetic resources are generally of alternative nature strongly support this proposal.

It is believed that at least 10% product increase can be achieved obtaining varieties of wheats to be developed by transferring recessive vernalization (*Vrn*) gene to the high yielding spring wheat varieties or to promising lines according to the procedure and backcrossing three to five times or more until be sure and selecting plant tolerant to winter conditions each time.

Table 1. Genotype names and growing habits in the trial.

Variety Number	Line or Variety name	Growing Habit	Variety Number	Line or Variety Name	Growing Habit
1	Anza	Winter	16	Pitic	Winter
2	Anza	Spring	17	Pitic	Spring
3	Anza	Spring	18	Pitic 62	Spring
4	Yecora Rojo	Winter	19	Phoenix (WW33)	Winter
5	Yecora Rojo	Spring	20	Yolo	Spring
6	YecoraRojo	Spring	21	Anza	Winter
7	Tanori	Winter	22	Anza	Spring
8	Tanori	Spring	23	Yecora Blanco	Winter
9	Tanori 71	Spring	24	Tanoro	Winter
10	Portola	Winter	25	Tanori	Spring
11	Portola	Spring	26	Pitic	Winter
12	Portola	Spring	27	Seri 82	Spring
13	SieteCerros	Winter	28	Cumhuriyet 75	Spring
14	SieteCerros	Spring	29	Ata 81	Spring
15	SieteCerros 66	Spring	30	Kaklıç 88	Spring

Table 2. Locations of trials over years.

Locations	Years		
	1991-92	1992-93	1993-94
İzmir (Menemen)	•	•	•
Denizli (Sarayköy)	•	•	•
Muğla (Milas)	•	•	
Balikesir (Merkez)		•	•
Çanakkale (Merkez)		•	
Sakarya (Adapazarı)		•	•
Samsun (Merkez)		•	•
Diyarbakır (Merkez)		•	•
Şanlıurfa (Akçakale)		•	•
Adana (Yüreğir)		•	•
Antalya (Aksu)			•

• Implemented locations

Table 3. Grain yield average of location over years (kg/ha).

Locations	Years	
	1991-92	1992-93
İzmir	7310 a	6153 a
Denizli	6707 b	6705 a
Muğla	5013 c	6076 a
LSD $_{(\alpha=0.05)}$	**414**	**636**

Table 4. Averages of grain yield on locations over years (kg/ha).

Growing years	Locations			
	İzmir	Denizli	Muğla	Şanlıurfa
1991-92	7310 a	6707 a	5013 b	-
1992-93	6153 b	6705 a	6076 a	4662 b
1993-94	5136 c	6611 a	-	5630 a
LSD $_{(\alpha=0.05)}$	**414**	**449**	**824**	**622**

Table 5. Averages of combined grain yields over years on locations (kg/ha).

Locations	Combined grain yield for two years (kg/ha)
Denizli	6683 a
Balıkesir	5650 b
İzmir	5644 b
Diyarbakır	5042 c
Adana	4994 c
Sakarya	4588 d
Samsun	3826 e
LSD $_{(\alpha=0.05)}$	**1.136**

Table 6. Combined 7 locations and 2 years averages of genotype for grain yield.

Genotypes	(kg/ha)
Anza-S	5725 a
Anza-W	5711 a
Seri 82	5704 a
Phoenix (WW33)	5679 a
Kaklıç	5672 a
Ata 81	5646 a
Anza-W	5576 a
Anza-S	5510 ab
Anza	5508 ab
Yecora Rojo-W	5490 ab
LSD $_{(\alpha=0.05)}$	**235.2**

Table 7. Averages of straw yield combined on location over two years (kg/ha).

Locations	(kg/ha)
Denizli	9923 a
Diyarbakır	8636 b
İzmir	8338 c
Balıkesir	7653 d
Samsun	7433 e
Sakarya	7022 f
Adana	5988 g
LSD $_{(\alpha=0.05)}$	**195.3**

Table 8. Averages of genotype combined 7 locations and 2 years for straw yield.

Genotypes	(kg/ha)
Anza-W	8618 a
Ata 81	8560 ab
Anza-S	8275 abc
Siete Cerros-S	8267 abc
Siete Cerros-W	8237 abc
LSD $_{(\alpha=0.05)}$	**404.3**

Table 9. Averages of genotype combined 7 locations and 2 years for biological yield.

Locations	Biological yield (kg/ha)
Denizli	15910 a
İzmir	13980 b
Diyarbakır	13680 c
Balıkesir	13300 d
Sakarya	11610 e
Samsun	11260 f
Adana	10980 g
LSD $_{(\alpha=0.05)}$	**260**

Table 11. Percentage of harvest indexes according to data of locations over years.

Locations	Harvest index (%)
Adana	45.66 a
Balıkesir	42.65 b
Denizli	42.53 b
İzmir	40.34 c
Sakarya	39.27 d
Diyarbakır	37.55 e
Samsun	34.10 f
LSD $_{(\alpha=0.05)}$	**0.6293**

Table 13. Averages of thousand kernel weight combined data of locations (g).

Locations	Thousand kernel weight
Sakarya	38.96 a
Balıkesir	37.10 b
Diyarbakır	35.50 c
Adana	35.42 cd
Samsun	35.06 d
İzmir	32.16 e
LSD $_{(\alpha=0.05)}$	**0.3883**

Table 15. Comparison of standard varieties and winter isoline having the same grain filling period.

Standard varieties and winter isoline	Grain filling period (number of days)
Tanori-W	40.92
Cumhuriyet 75	40.08
Seri 82	39.92
LSD $_{(\alpha=0.05)}$	**1.272**

Table 10. Biological yields of the first group of genotypes combined over years and location.

Genotypes	Biological yield (kg/ha)
Anza-W	14330
Ata 81	14210
Anza-S	14000
Phoenix	13850
LSD $_{(\alpha=0.05)}$	**542**

Table 12. Averages of test weights combined data of locations.

Locations	Test weight averages of locations (kg)
Balıkesir	76.91 a
İzmir	76.72 ab
Sakarya	76.51 b
Adana	74.86 c
Diyarbakır	72.60 d
Samsun	72.14 e
LSD $_{(\alpha=0.05)}$	**0.2997**

Table 14. Averages of plant height combined data of locations (cm).

Locations	Plant height
Sakarya	97.37 a
Adana	95.94 b
Denizli	95.42 b
İzmir	93.64 c
Diyarbakır	92.16 d
Samsun	87.95 e
Balıkesir	84.91 f
LSD $_{(\alpha=0.05)}$	**0.6075**

Table 16. Percentage of protein content of locations (1992-93).

Locations	% of grain protein
İzmir	14.90 a
Sakarya	14.55 b
Diyarbakır	14.33 b
Adana	13.80 c
Çanakkale	13.64 cd
Denizli	13.45 d
Muğla	13.42 d
Samsun	12.44 e
Balıkesir	11.27 f
Şanlıurfa	10.89 g
LSD $_{(\alpha=0.05)}$	**0.2716**

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Sowing Time, Variety and Seed Fungicide Application Effect on Grain Quality Properties of Bread Wheat

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ABSTRACT

In the present study, Esperia, Genesi, Anapo bread wheat varieties (early, middle and late-maturing time, respectively) were used as materials and the seeds of these varieties were treated with 4 different seed fungicides (Prothioconazole + Tebuconazole, Carboxin + Thiram, Prochloraz + Triticonazole and Control) before sowing. After that, these 3 varieties were sown on November 1, November 15 and November 30. The quality characters such as test weight, gluten ratio, gluten index, sedimentation value, sunn pest damage ratio, black point ratio and protein ratio were investigated. When the quality features are analyzed in terms of three different sowing times, the highest quality values are obtained from 2nd sowing time, while the lowest values are obtained from the cultivation on 1st sowing time. Among the wheat varieties, the highest quality values were obtained in the Esperia variety, while the lowest values were the earliest variety Anapo. When the effects of four different seed fungicide applications on the quality characteristics are examined, the highest means were in Carboxin + Thiram and Prochloraz + Tiriticonazole fungicide applications for gluten ratio; were in Carboxin + Thiram, Prothioconazole + Tebuconazole and Prochloraz + Tiriticonazole fungicide applications for gluten index and protein ratio. The most appropriate seed fungicide applications were Carboxin + Thiram and Prothioconazole + Tebuconazole for test weight, black point ratio and sunn pest damage ratio, and the Prob thioconazole + Tebuconazole seed fungicide application for sedimentation value. Higher quality values were obtained in all three seed fungicide applications for all quality characteristics compared to control applications.

Keywords: wheat, sowing time, fungicide, gluten, sedimentation, protein ratio

Introduction

The resistance of living organisms to biotic and abiotic stress factors is closely related to the living creature's genetic structure and the environmental conditions in which they grow. Plants are significantly affected by biotic stress factors. Fungi such as *Fusarium culmorum*, *Fusarium pseudograminearum*, *Gaeumannomyces graminis*, *Bipolaris sorokiniana* and *Rhizoctonia cerealis* cause root and root rot disease in wheat. These fungi that cause disease are of soil origin and can be transported by seed. Numerous studies have been conducted on root and root throat rot and yield loss caused by nematodes in wheat. Studies in Europe, USA, West Asia, North Africa, Australia and Canada show that the yield loss in cereals ranges from 5-50% due to these soil-borne factors (Singh *et al*. 2005; Nicol and Rivoal 2008).

In recent years, a significant increase has been observed in the root and crown rot disease of wheat in the Thrace region. They stated that the decrease in the percentage of disease severity among the cultivars used in the study was highest in Golia cultivar (Köycü and Özer 2014). The genotypic (variety) structure of the plants, the environmental conditions in which the plants are grown, the soil characteristics and the cultural practices applied during the growing process are important in the effectiveness of the plants. According to the studies carried out in the areas infected with the disease in our country, the yield loss is up to 42%

due to root and crown rot disease and 45% due to nematodes (Hekimhan *et al*. 2004; Nicol *et al*. 2005). According to a study, using different types of grain, the yield increase with the use of nematicides ranged from 7 to 89% (Bolat *et al*. 2004). According to the results of the surveys conducted in recent years, *F. culmorum* was found in 14% out of 518 plant samples taken in dry farming areas. The prevalence ratio of *B. sorokiniana* and *F. pseudograminearum* was 10% and 2%, respectively (Bağcı *et al*. 2006). The study was carried out for 2 years to determine the effect of sowing time, ripening time and seed fungicide use on root and crown root damage in bread wheat varieties.

Materials and Methods

The research was carried out according to split-split-plot experimental design in the trial areas of the Department of Field Crops, Faculty of Agriculture, University of Tekirdağ Namık Kemal. Esperia (1), Anapo (2), and Genesi (3) varieties, which are in the early, medium and late maturation groups, respectively, were used as materials in the study. Three wheat varieties were sown at three different times, on November 1 (1st sowing), November 15 (2nd sowing) and November 30 (3rd sowing). The seeds of these varieties were treated with 4 different seed fungicides (Carboxin + Thiram (1), Prothioconazole + Tebuconazole (2), Prochloraz + Tiriticonazole (3) and control (4)). Sowing was done in plots of 6.12 square meters (0.17 m between rows, 6 m in rows) consisting of 6 rows) by sowing machine, and sowing density has been adjusted to 500 plants per square meter. The experiment was carried out in 3 replications. To prevent weed development, broad leaf weed + grass herbicide was applied. No chemical was sprayed against diseases and pests in the trial area. For the necessary measurements and weighing, 10 plants were randomly sampled from each plot at harvest maturity and the plots were harvested by the plot combine harvester. The quality characters such as test weight, gluten ratio, gluten index, sedimentation value, sunn pest damage ratio, black point ratio and protein ratio were investigated. The data obtained in the experiment were analyzed by using the JUMP 5.0 statistical package program, and the differences between the averages obtained were determined by the LSD test.

Results and Discussion

Gluten ratio, gluten index and test weight

Variance analysis was performed for gluten ratio, gluten index and test weight values to determine the effect of different sowing time, variety and different seed fungicide applications on grain quality in bread wheat. According to the results of the analysis of variance, the sowing time, variety and seed fungicide affected gluten ratio and test weight significantly. Studies in Europe, USA, West Asia, North Africa, Australia and Canada showed that the yield loss in grain ranges from 5 to 50% due to root and crown rot disease (Singh *et al*. 2005; Nicol and Rivoal 2008). The effect of fungicide application on seed was found to be statistically significant while the effects of sowing time and variety on the gluten index were non-significant. The mean and significances for gluten ratio, gluten index and test weight are given in Table 1.

The highest gluten ratio is obtained at the latest in sowing time (3rd sowing time) with 30.47%, while the lowest value is obtained in the same statistical group the first and second sowing time. Among the varieties, the highest gluten ratio was found in the Esperia variety, while the lowest was the earliest variety Anapo with 24.25%. According to studies carried out in disease-contaminated areas, product losses occur up to 42% due to root and crown rot disease and up to 45% due to nematodes (Hekimhan *et al*. 2004; Nicol *et al*. 2005). In fungicide applications on seed, the highest gluten ratio was in Carboxin + Thiram and Prochloraz + Tiriticonazole application, the lowest value was obtained in standard plots where no fungicide was applied.

In the case of gluten index, the planting time and differences between cultivars were statistically non-significant. The highest gluten index value was obtained in Prochloraz + Triticonazole, Prothioconazole + Tebuconazole and Carboxin + Thiram fungicide applications. According to a study on different cereal varieties, the increase in yield with the use of nematicides varied between 7 and 89% (Bolat *et al*. 2004).

The 2nd sowing time with 75.92 kg/hl gave the highest test weight value, while the lowest value was at the 3rd sowing time with 72.86 kg/hl. Among varieties, the highest test weight was found for Genesi and Esperia varieties with 75.31 and 74.86 kg/hl, respectively.

The Carboxin + Thiram and Prothioconazole + Tebuconazole fungicide applications on seed, obtained the highest test weight values 74.85 and 74.63 kg/hl, respectively, were the most suitable applications for test weight, while the lowest value of test weight (74.03 kg/hl) was obtained in control. In their study on root and crown rot in wheat, grain yields ($P<0.01$), drug administration ($P<0.003$), disease severity ($P<0.05$), doses used ($P<0.01$) and effects of fungicide on disease severity ($P<0.01$) was found statistically significant. Grain yields were statistically significant

in Triticonazole (366-17.7), Difenoconazole (360-15.8), Diniconazole (340-9.3) and Carboxin (338-8.7). The sowing time x variety x seed fungicide interaction means and their significances for gluten ratio and test weight are given in Table 2.

When the cultivation time x cultivar x seed fungicide interaction was examined, gluten ratio varied between 35.33 and 19.20%. The highest gluten ratio was obtained in Prochloraz + Triticonazole fungicide application at the 3rd sowing time of the Genesi variety, followed by Prothioconazole + Tebuconazole and Carboxin + Thiram medication at the 3rd sowing time. The lowest gluten ratio value was obtained in the seed that not fungicide application of the Anapo variety at the 1st sowing time. The highest value in terms of test weight was obtained in the application of Carboxin + Thiram at the 2nd sowing time of Genesi variety with 78.00 kg/hl, followed by the application of Carboxin + Thiram at the second sowing of Esperia with 77.67 kg/hl. The lowest value was in the application of Carboxin + Thiram seed fungicide at the time of the 3rd sowing of Anapo variety with 70.33 kg/hl.

Sedimentation value and Protein ratio

The results of variance analysis of the data showed that sowing time, cultivar and seed fungicide application had a statistically significant effect on the sedimentation value and protein ratio. The fact that *F. culmorum* isolates are frequently obtained in *Fusarium* genus reveals the importance of the Thrace Region (Köycü and Özer 2014). Averages and their significance are given in Table 3.

The highest sedimentation value was found at the time of the 3rd sowing with 47.97 ml, which is a very high value compared to other sowing times. Among the cultivars, the highest sedimentation value was in Genesi and Esperia cultivars with 42.04 and 41.69 ml, respectively, while the lowest was in Anapo cultivars with 31.66 ml. More than 5000 lines were selected by inoculating over 5000 breeding lines under field conditions. More than 50 wheat genotypes have shown resistance to root and root throat (Nicol *et al*. 2005). The highest sedimentation value in seed medicines was 40.85 ml, while Prothioconazole + Tebuconazole was in the drug application, while the lowest was 36.22 ml. High nitrogen doses increase root and root throat disease in wheat (Smiley *et al*. 1996).

In the study, the highest protein ratio was obtained from the 3rd sowing time with 13.73%. Among the varieties, the highest protein ratio was 13.13 and 13.02% for Esperia and Genesi varieties, respectively, while Anapo, the early variety, was the lowest protein ratio with 11.85%. Carboxin + Thiram, Prothioconazole + Tebuconazole and Prochloraz + Tiriticonazole applications seed fungicide applications gave the highest protein ratio values, while the lowest protein rate was obtained in the non-fungicide application. Average values and their significances of sowing time x variety x seed fungicide interaction for sedimentation value and protein ratio are given in Table 4.

It is revealed from Table 4 that the mean sedimentation value of bread wheat varies ranged between 56.33 and 25.00 ml. The highest sedimentation value was obtained with the application of Prothioconazole + Tebuconazole application at the 3rd sowing time of the Genesi variety with 56.33 ml, followed by Carboxin + Thiram, Prochloraz + Tiriticonazole and control at the 3rd sowing time of the Genesi variety. The lowest sedimentation value was obtained from the control application of Anapo variety at the 1st sowing time with 25.00 ml.

In the case of protein ratio, the highest value was obtained in Prochloraz + Triticonazole fungicide application at the time of the 3rd sowing of the Genesi variety with 14.80%, followed by the application of Prothioconazole + Tebuconazole in the 3rd sowing time of the Genesi variety. Spolti *et al*. (2013) investigated the effect of fungicide with Metconazole and Metconazole + Pyraclostrobin in the wheat varieties of 2009 and reported the highest grain yield increase with the application of Metconazole + Pyraclostrobin fungicide mixture.

Black point and Sunn pest damage ratio

The results of variance analysis for black point and sunn pest damage ratio indicate that sowing time and variety effect on the black point was statistically insignificant, while the effect of seed fungicide application was statistically significant. In their study on wheat, they revealed that some fertilizer form and pesticide use can give effective results in reducing root and root rot (Akgül and Erkılıç 2016). The effect of sowing time on sunn pest damage ratio is insignificant, but the effect of cultivar and seed fungicide application is statistically significant. The mean and their significances for black point and sunn pest damage ratio are given in Table 5.

The sowing time and the effect of the variety on black point ratio were statistically insignificant. However, it is seen from Table 5 that the lowest black point ratio is at the time of the 2nd sowing time and the highest is at the 1stsowing time. Among the varieties, Esperia was the lowest lack point ratio. When the seed fungicide is examined, it is understood that the lowest black point values are obtained in

Prothioconazole + Tebuconazole, Carboxin + Thiram and Prochloraz + Tiriticonazole fungicide applications, while the highest rate was obtained from controls.

The highest value for sunn pest damage ratio was determined in the 1st sowing time. As for the varieties, the highest sunn pest damage ratio was in Esperia, while the lowest was Genesi, the latest variety. In the case of seed fungicide application, Carboxin + Thiram drug application was the highest damage, while the lowest value was in non-fungicide ones.

Since the sowing time x variety x seed fungicide interaction for the black point ratio and the sunn pest damage ratio are statistically significant, the averages obtained and their significance is given in Table 6.

As a result of different sowing time and seed fungicide applications, wheat varieties have averages ranging from 3.3-1.00% for black point ratio and varying between 1.0-2.0% for sunn pest damage ratio. The highest black point ratios were obtained in Carboxin + Thiram fungicide application at the 3rd sowing time of Genesi variety with 3.33% and are not applied fungicide (control) at the 1st sowing time of Anapo variety.

However, the lowest value was obtained in none fungicide application (control) at the 3rd sowing time of Anapo variety with 1%. While the sunn pest damage ratio was generally at the level of 1%, the highest ratio was obtained with the application of Carboxin + Thiram fungicide at the 1st sowing time of Esperia cultivar and the 3rd sowing time of the Esperia cultivar in the application of Prothioconazole + Tebuconazole fungicide.

Conclusion

The data showed that sowing time, cultivar and seed pesticide application effects were statistically significant on the quality characteristics in bread wheat. It was understood that there were decreases in quality characteristics in early sowing, and there was an increase in the quality characteristics as the sowing delayed. Among the varieties, while the quality characteristics were lower as expected in the early varieties, the quality characteristics were high in the most recent varieties. It has been determined that seed fungicide application causes significant improvements in all quality features.

Table 1. Average values and significance groups for gluten ratio and test weight.

Gluten ratio (%)									
Sowing time			**Variety**			**Seed fungicide application**			
1	2	3	1	2	3	1	2	3	4
24.67 b	24.28 c	30.47 a	27.89 a	24.25 c	27.28 b	27.70 a	26.37 b	27.37 a	24.44 c
LSD : 0.970			**0.504**			**0.437**			
Gluten index									
Sowing time			**Variety**			**Seed fungicide application**			
1	2	3	1	2	3	1	2	3	4
92.25	93.8	93.33	93.00	93.472	92.912	92.93 ab	93.52 a	94.4 a	91.59 b
						LSD: 1.797			
Test weight (kg/l)									
Sowing time			**Variety**			**Seed fungicide application**			
1	2	3	1	2	3	1	2	3	4
74.53 b	75.92 a	72.86 c	74.86 a	73.14 b	75.31 a	74.63 ab	74.85 a	74.22 bc	74.04 c
LSD : 1.218			**0.712**			**0.528**			

Sowing times : 1.(1 November), 2. (15 November), 3. (30 November); **Varieties :** 1 (Esperia), 2 (Anapo), 3 (Genesi)
Seed fungicides: 1 (Carboxin + Thiram), 2 (Prothioconazole + Tebuconazole), 3 (Prochloraz + Tiriticonazole) and 4 (Control)

Table 2. Average values and significance groups regarding the gluten ratio (%) and test weight (kg/hl) in the sowing time x variety x seed fungicide interaction.

Sowing time x variety x seed fungicide interaction (Gluten ratio)				Sowing time x variety x seed fungicide Interaction (Test weight)			
1*1*1	32.00 cd	2*2*3	21.00 n	1*1*1	72.00 lmn	2*2*3	75.33 efg
1*1*2	29.00 ef	2*2*4	19.67 o	1*1*2	75.00 fgh	2*2*4	73.33 ijk
1*1*3	31.33 d	2*3*1	25.33 i	1*1*3	74.33 ghi	2*3*1	78.00 a
1*1*4	27.67 gh	2*3*2	25.33 i	1*1*4	75.00 fgh	2*3*2	74.00 hij
1*2*1	22.33 c	2*3*3	25.67 i	1*2*1	73.00 jkl	2*3*3	76.33 cde
1*2*2	21.33 mn	2*3*4	23.67 jk	1*2*2	73.00 jkl	2*3*4	77.67 ab
1*2*3	21.00 n	3*1*1	27.33 h	1*2*3	73.00 jkl	3*1*1	75.00 fgh
1*2*4	19.33 o	3*1*2	27.33 h	1*2*4	74.00 hij	3*1*2	73.33 ijk
1*3*1	25.33 i	3*1*3	28.00 gh	1*3*1	76.33 cde	3*1*3	71.67 mno
1*3*2	23.33 k	3*1*4	25.67 i	1*3*2	77.00 abc	3*1*4	74.00 hij
1*3*3	23.33 k	3*2*1	32.67 c	1*3*3	76.67 bcd	3*2*1	70.33 p
1*3*4	20.00 o	3*2*2	29.33 e	1*3*4	75.00 fgh	3*2*2	71.33 nop
2*1*1	28.33 fg	3*2*3	32.67 c	2*1*1	77.67 ab	3*2*3	70.67 op
2*1*2	25.67 i	3*2*4	27.33 h	2*1*2	76.33 cde	3*2*4	75.33 efg
2*1*3	28.00 gh	3*3*1	33.67 b	2*1*3	77.33 abc	3*3*1	73.67 ijk
2*1*4	24.33 j	3*3*2	34.00 b	2*1*4	76.67 bcd	3*3*2	73.67 ijk
2*2*1	22.33 l	3*3*3	35.33 a	2*2*1	75.67 def	3*3*3	72.67 klm
2*2*2	22.00l m	3*3*4	32.33 c	2*2*2	72.67 klm	3*3*4	72.67 kml
LSD:		**0.980**				**1.186**	

Sowing times : 1.(1 November), 2. (15 November), 3. (30 November); **Varieties :** 1 (Esperia), 2 (Anapo), 3 (Genesi)
Seed fungicides: 1 (Carboxin + Thiram), 2 (Prothioconazole + Tebuconazole), 3 (Prochloraz + Tiriticonazole) and 4 (Control)

Table 3. Mean and significances of sedimentation and protein ratio

Sedimentationvalue (ml)									
Sowing time			**Variety**			**Seed fungicide application**			
1	2	3	1	2	3	1	2	3	4
34.00 b	33.44 b	47.97 a	41.69 a	31.66 b	42.06 a	39.37 b	40.85 a	37.44 c	36.22 d
LSD : 0.922			**0.643**			**0.572**			
Protein ratio (%)									
Sowing time			**Variety**			**Seed fungicide application**			
1	2	3	1	2	3	1	2	3	4
12.12 b	12.17 b	13.72 a	13.13 a	11.85 c	13.02 b	12.84 a	12.79 a	12.74 a	12.31 b
LSD : 0.051			**0.069**			**0.105**			

Sowing times : 1.(1 November), 2. (15 November), 3. (30 November); **Varieties :** 1 (Esperia), 2 (Anapo), 3 (Genesi)
Seed fungicides: 1 (Carboxin + Thiram), 2 (Prothioconazole + Tebuconazole), 3 (Prochloraz + Tiriticonazole) and 4 (Control)

Table 4. The means and significances of sowing time x variety seed fungicide interaction for sedimentation value (ml) and protein ratio (%).

Sowing time x variety x seed fungicide interaction (Sedimentation value)				Sowing time x variety x seed fungicide interaction (Protein ratio)			
1*1*1	30.00 m	2*2*3	25.33 r	1*1*1	13.60 de	2*2*3	11.03 pq
1*1*2	43.67 g	2*2*4	26.67 q	1*1*2	13.70 cd	2*2*4	11.07 pq
1*1*3	44.00 g	2*3*1	40.33 i	1*1*3	13.93 d	2*3*1	12.53 jkl
1*1*4	43.67 g	2*3*2	37.33 j	1*1*4	12.70 hij	2*3*2	12.90 gh
1*2*1	30.33 m	2*3*3	35.33 k	1*2*1	11.33 o	2*3*3	12.90 gh
1*2*2	27.00 q	2*3*4	35.67 k	1*2*2	11.07 pq	2*3*4	12.47 jkl
1*2*3	27.33 pq	3*1*1	54.33 b	1*2*3	10.93 q	3*1*1	13.43 ef
1*2*4	25.00 r	3*1*2	50.00 c	1*2*4	11.10 opq	3*1*2	13.37 ef
1*3*1	35.00 k	3*1*3	43.67 g	1*3*1	12.63 ijk	3*1*3	13.60 de
1*3*2	42.33 h	3*1*4	47.00 e	1*3*2	12.17 m	3*1*4	13.00 g
1*3*3	30.00 m	3*2*1	42.33 h	1*3*3	11.10 opq	3*2*1	13.50 def
1*3*4	29.67 mn	3*2*2	37.33 j	1*3*4	11.13 opq	3*2*2	13.27 f
2*1*1	39.33 i	3*2*3	48.33 d	2*1*1	12.83 ghi	3*2*3	13.73 cd
2*1*2	45.33 f	3*2*4	33.67 l	2*1*2	12.40 klm	3*2*4	12.37 lm
2*1*3	28.67 no	3*3*1	54.33 b	2*1*3	12.60 il	3*3*1	14.47 b
2*1*4	30.67 m	3*3*2	56.33 a	2*1*4	12.43 kl	3*3*2	14.60 ab
2*2*1	28.33 op	3*3*3	54.33 b	2*2*1	11.23 op	3*3*3	14.80 a
2*2*2	28.33 op	3*3*4	54.00 b	2*2*2	11.60 n	3*3*4	14.53 b
LSD:		**1.283**				**0.237**	

Sowing times : 1.(1 November), 2. (15 November), 3. (30 November); **Varieties** : 1 (Esperia), 2 (Anapo), 3 (Genesi)
Seed fungicides: 1 (Carboxin + Thiram), 2 (Prothioconazole + Tebuconazole), 3 (Prochloraz + Tiriticonazole) and 4 (Control)

Table 5. The mean and their significances for black point and sunn pest damage ratio.

Black point ratio (%)									
Sowing time			**Variety**			**Seed fungicide application**			
1	2	3	1	2	3	1	2	3	4
2.58	2.25	2.44	2.33	2.36	2.58	2.33 b	2.30 b	2.41 ab	2.67 a
						LSD : 0.265			
Sunn pest damage ratio (%)									
Sowing time			**Variety**			**Seed fungicide application**			
1	2	3	1	2	3	1	2	3	4
1.16	1.06	1.09	1.28 a	1.03 b	1.00 c	1.18 a	1.13 ab	1.09 bc	1.02 c
LSD :				**0.102**		**0.079**			

Sowing times : 1.(1 November), 2. (15 November), 3. (30 November); **Varieties :** 1 (Esperia), 2 (Anapo), 3 (Genesi)
Seed fungicides: 1 (Carboxin + Thiram), 2 (Prothioconazole + Tebuconazole), 3 (Prochloraz + Tiriticonazole) and 4 (Control)

Table 6. The means and significances of sowing time x variety seed fungicide interaction for black point ratio (%) and sunn pest damage ratio (%).

Sowing time x variety x seed fungicide interaction (Black point ratio)				Sowing time x variety x seed fungicide interaction (Sunn pest damage ratio)			
1*1*1	2.27 cd	2*2*3	3.00 ab	1*1*1	2.00 a	2*2*3	1.00 c
1*1*2	2.67 bc	2*2*4	3.00 ab	1*1*2	1.00 c	2*2*4	1.00 c
1*1*3	2.00 d	2*3*1	2.00 d	1*1*3	1.63 b	2*3*1	1.00 c
1*1*4	3.00 ab	2*3*2	2.00 d	1*1*4	1.10 c	2*3*2	1.00 c
1*2*1	2.33 cd	2*3*3	2.00 d	1*2*1	1.00 c	2*3*3	1.00 c
1*2*2	2.00 d	2*3*4	3.00 ab	1*2*2	1.07 c	2*3*4	1.00 c
1*2*3	3.00 ab	3*1*1	3.00 ab	1*2*3	1.07 c	3*1*1	1.00 c
1*2*4	3.33 a	3*1*2	2.00 d	1*2*4	1.07 c	3*1*2	1.93 a
1*3*1	2.00 d	3*1*3	2.00 d	1*3*1	1.00 c	3*1*3	1.00 c
1*3*2	3.00 ab	3*1*4	3.00 ab	1*3*2	1.00 c	3*1*4	1.00 c
1*3*3	3.00 ab	3*2*1	2.00 d	1*3*3	1.00 c	3*2*1	1.00 c
1*3*4	2.33 cd	3*2*2	2.00 d	1*3*4	1.00 c	3*2*2	1.07 c
2*1*1	2.00 d	3*2*3	2.67 d	2*1*1	1.60 b	3*2*3	1.07 c
2*1*2	2.00 d	3*2*4	1.00 e	2*1*2	1.10 c	3*2*4	1.00 c
2*1*3	2.00 d	3*3*1	3.33 a	2*1*3	1.00 c	3*3*1	1.00 c
2*1*4	2.00 d	3*3*2	3.00 ab	2*1*4	1.00 c	3*3*2	1.00 c
2*2*1	2.00 d	3*3*3	2.00 d	2*2*1	1.00 c	3*3*3	1.00 c
2*2*2	2.00 d	3*3*4	3.33 a	2*2*2	1.00 c	3*3*4	1.00 c
LSD:		**0.638**				**0.179**	

Sowing times : 1.(1 November), 2. (15 November), 3. (30 November); **Varieties** : 1 (Esperia), 2 (Anapo), 3 (Genesi)
Seed fungicides: 1 (Carboxin + Thiram), 2 (Prothioconazole + Tebuconazole), 3 (Prochloraz + Tiriticonazole) and 4 (Control)

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Evaluation of New Extra-Early Maturing Hybrids of Maize (*Zea mays* L.) for Grain Yield and Its Contributing Traits under Humid and Semi-Arid Conditions of Haryana

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ABSTRACT

This experiment was conducted under two different agro-climatic conditions of Haryana viz. humid conditions of Karnal and semi-arid conditions of Hisar during *kharif* 2015 to evaluate the performance of newly developed seven extra-early maturing hybrids of maize. The analysis of variance revealed significant differences among the hybrids for different characters. In humid conditions, hybrid Bio9637 (5243.0 kg/ha) was highest yielder followed by hybrid Vivek Hybrid 43 (5047.0 kg/ha), Vivek Hybrid 21 (4631.0 kg/ha), EH2236 (4142.0 kg/ha), Bio9681 (3694.0 kg/ha), Prakash (3644.0 kg/ha) and AH1317 (2972.0 kg/ha). In semi-arid conditions, Prakash (5017.0 kg/ha) was significantly superior and followed by Vivek Hybrid 43 (4977.0 kg/ha), Vivek Hybrid 21 (4294.0 kg/ha), AH1317 (4091.0 kg/ha), EH2236 (3830.0 kg/ha), Bio9637 (2990.0 kg/ha), Bio9681 (2908.0 kg/ha). Likewise, on average basis, Vivek Hybrid 43 with an average yield 5012.0 kg/ha was at the top yielder and followed by Vivek Hybrid 21 (4462.5 kg/ha), Prakash (4330.5 kg/ha), Bio9637 (4116.5 kg/ha), EH2236 (3986.0 kg/ha), AH1317 (3531.5 kg/ha), Bio9681 (3301.0 kg/ha). The grain yield mean performance was high in humid conditions (5243.0 kg/ha) as compared to in semi-arid conditions (5017.0 kg/ha) due to more availability of soil moisture and nutrients.

Keywords: Yield performance, extra-early maturity, maize, hybrids

Introduction

Worldwide, maize (*Zea mays* L.) is considered as an important crop, which is cultivated for food, feed and fodder and also utilized as a raw material for large number of industrial products. In India, it is cultivated as a dual-purpose crop, for grain as well as fodder. Maize being a C_4 plant, it has an excellent potential and able to produce the maximum carbohydrate per day (Dayal *et al*. 2014). The plants of maize are fast growing, succulent, sweet, palatable, high yielding, nutritious and free from toxicants and may be utilized safely to feed animals at any stage of crop growth. The grains of maize are affluent in starch, protein, fat, vitamins and mineral nutrients (Arya *et al*. 2015). In India, maize is cultivated in about 8.55 mha with a production of 21.7 m ton and the average yield is 2.51 t/ha (Singh *et al*. 2014). It is considered as one of the most flexible crops having wide adaptability under varied agro-climatic conditions (Sharma *et al*. 2014). Maize is extremely cross-pollinated cereal plant species. Therefore, open pollinated varieties (OPV), composite/synthetic varieties and hybrids are used for commercial cultivation. Nevertheless, the maximum yield potential invests only in hybrid cultivars. Therefore, more stress is always given on the development and evaluation of maize hybrids rather than the OPVs. Keeping the discussion in view, there is a need to evaluate maize hybrids for their production performance under prevailing Haryana agro-climatic conditions.

Materials and Methods

The experiment was conducted under two different agro-climatic conditions of Haryana *viz*. semi-arid conditions of Hisar at RDS Seed Farm, CCS HAU, Hisar and humid conditions of Karnal at CCS HAU Regional Research Station, Uchani, Karnal during *kharif* 2015 with the objective to evaluate the performance of newly developed late maturing maize hybrids under prevailing Haryana agro-climatic conditions. Haryana is the part of Indo-Gangatic alluvial plains, a tectonic basic with covering alluvial deposits brought down during Pleistocene age. The RDS Seed Farm lies at 29°47' N latitude and 75°47' E longitude in the west of Hisar-Barwala road with loamy sand (Type Haplusteptsis) soil. The RRS Uchani, Karnal research area is lies at 29°42' N latitude and 77°02' E longitudes in the east of Karnal-Chandigarh road with mildly alkaline sandy loam (Type Ustrochrept) soil. The experimental material was comprised of seven medium maturing maize hybrids including one check, which was received from IIMR, New Delhi. The experiment was planted on 2 July, 2015 at Karnal and 3 July, 2015 at Hisar in randomized block design with three replications having plot size of 4x3 m^2 with row to row and plant to plant spacing of 75 and 15 cm, respectively. To raise a healthy crop, the N, P, K fertilizers were applied 150, 60, 60 kg/ha, respectively, at both the locations. Six irrigations were applied at different growth stages of the crop. Data were recorded for plant height (cm), grain yield (kg/ha), plant stand at harvest, days to 50% pollen shedding, days to 50% silking, days to 75% husk drying, and ear placement height (cm). The data recorded were analyzed for mean, coefficient of variation, and critical difference by OPSTAT.

Results and Discussion

The analysis of variance results of the present investigation revealed the considerable differences among the different maize hybrids for different characters. This indicated that adequate variability is there among the different hybrids. The mean performance of the different maize hybrids under different parameters is presented below:

Grain yield

The results of grain yield (kg/ha) are presented in Table 1 revealed that in humid conditions at Karnal, Bio9637 (5243.0 kg/ha) was top yielder and significantly superior over the other hybrids, which was followed by Vivek Hybrid 43(5047.0 kg/ha), Vivek Hybrid 21(4631.0 kg/ha), EH2236 (4142.0 kg/ha), Bio9681 (3694.0 kg/ha), Prakash (3644.0 kg/ha) and AH1317 (2972.0 kg/ha). In semi-arid conditions at Hisar, Prakash (5017.0 kg/ha) was significantly superior over the other hybrids, and followed by Vivek Hybrid 43 (4977.0 kg/ha), Vivek Hybrid 21 (4294.0 kg/ha), AH1317 (4091.0 kg/ha), EH2236 (3830.0 kg/ha), Bio9637 (2990.0 kg/ha), Bio9681 (2908.0 kg/ha) Likewise, on the basis average over the locations, Vivek Hybrid 43 with an average yield 5012.0 kg/ha was at the top and followed by Vivek Hybrid 21 (4462.5 kg/ha), Prakash (4330.5 kg/ha), Bio9637 (4116.5 kg/ha), EH2236 (3986.0 kg/ha), AH1317 (3531.5 kg/ha), Bio9681 (3301.0 kg/ha). Above findings were also supported by Dhaka *et al*. (2014), Suthar *et al*. (2014), Arya *et al*. (2015), and Nidhi *et al*. (2019). The grain yield mean performance was high in humid conditions (5243.0 kg/ha) as compared to in semi-arid conditions (5017.0 kg/ha). Higher grain yield in humid condition was observed due to more availability of soil moisture and nutrients. More availability of water and nutrients also resulted in higher grain yield production in pearl millet (Arya *et al.* 2009;2014). Grain yield is a polygenic character which is considerably affected by environmental temperature, soil moisture and nutritional status of field during crop growth and especially at grain filling (Preeti *et al.* 2016). Moreover, different genotypes respond differently under different environments (Yadav *et al*. 2010;2014).

Kernel shelling (%)

It is evident from Table 1 that in humid conditions, maximum kernel shelling (%) was found in hybrid, EH2236 (82.30%) which was followed by Prakash (81.30%), Vivek Hybrid 21 (81.30%), Vivek Hybrid 43 (80.60%), Bio9637 (80.00%), AH1317 (79.70%) and Bio9681 (79.70%). In semi-arid conditions, maximum grain shelling (%) was in Prakash (85.70%) and followed by Vivek Hybrid 21 (85.10%), Vivek Hybrid 43 (85.10%), EH2236 (84.90%), Bio9681 (84.60%), Bio9637 (83.50%) and AH1317 (81.30%). But, on mean basis, maximum kernel shelling (%) was in EH2236 (83.60%) and followed by Prakash (83.50%), Vivek Hybrid 21 (83.20%), Vivek Hybrid 43 (82.85%), Bio9681 (82.15%), Bio9637 (81.75%) and AH1317 (80.50%). The kernel shelling (%) was high in semi-arid conditions (85.70%) as compared to in humid conditions (82.30%). Similar finding were also reported in maize by Arya *et al*. (2015) and Arya *et al*. (2016). The higher kernel shelling (%) in semi-arid conditions may be due to more photosynthetic accumulation in kernels.

Plant stand

In humid conditions, plant stand was maximum for AH1317 (63.90) and followed by Vivek Hybrid 43 (63.30), EH2236 (63.30), Prakash (63.10), Bio9637 (62.20), Bio9681 (62.20). Lowest plant stand was found

in Vivek Hybrid 21 (61.90). In semi-arid conditions, plant stand (000/ha) was maximum for AH1317 (61.40) and Bio9681 (61.40) and followed by EH2236 (61.10), Bio9637 (60.80), Prakash (60.80), Vivek Hybrid 21 (60.80) however, it was lowest was in Vivek Hybrid 43 (60.30). Likewise, on average basis, plant stand was maximum for AH1317 (62.65) and followed by EH2236 (62.20), Prakash (61.95), Bio9681 (61.80), Vivek Hybrid 43 (61.80), Bio9637 (61.50). While, the lowest plant stand was found in Vivek Hybrid 21 (61.35). The plant stand was high in humid conditions (63.90) as compared to in semi-arid conditions (61.40). Similar results were also reported in maize by Arya *et al*. (2015) and Arya *et al*. (2016).

Days to 50% pollen shedding

In humid conditions, Bio9637 (52.3 days) was earliest in pollen shedding and followed by Vivek Hybrid 43 (46.0 days) Prakash (46.0 days), AH1317 (46.3 days), and EH2236 (47.0 days). However, Vivek Hybrid 21 (48.3 days) and Bio9681 (49.0 days) were late in pollen shedding. Likewise, in semi-arid conditions, Vivek Hybrid 43 (38.3 days), Prakash (38.7 days), Vivek Hybrid 21 (39.0 days) were early in pollen shedding. However, Bio9637 (47.7 days), Bio9681 (45.0 days), AH1317 (44.0 days), EH2236 (44.0 days) were late in pollen shedding. On mean basis, Vivek Hybrid 43 (42.15 days), Prakash (42.35 days) and Vivek Hybrid 21 (43.65 days) were early in pollen shedding. However, Bio9637 (50.0 days), Bio9681 (47.0 days), EH2236 (45.5 days), AH1317 (45.15 days) were late in pollen shedding. Similar finding were also reported in maize by Dhaka *et al*. (2014) and Arya *et al*. (2016). The days to 50% pollen shedding was early in humid conditions (52.2 days) as compared to in semi-arid conditions (53.8 days).

Days to 50% silking

It is revealed from the Table 1 that in semi-arid conditions, Vivek Hybrid 43 (39.7 days), Vivek Hybrid 21 (40.0 days) and Prakash (40.0 days) were early in silking. However, Bio9637 (48.7 days), Bio9681 (46.0 days), AH1317 (45.3 days), EH2236 (45.3 days) were late in silking. In humid conditions, the hybrids viz. AH1317 (48.3 days), Vivek Hybrid 43 (48.7 days), Prakash (49.3 days), EH2236 (49.3 days) were early in silking. However, Bio9637 (54.7 days), Bio9681 (51.0 days), Vivek Hybrid 21 (50.3 days) were late in silking. Similarly, on the average basis over the locations, Vivek Hybrid 43 (44.2 days), Prakash (44.65 days), Vivek Hybrid 21 (45.15 days) were early in silking. Opposite to this, on the average basis over the locations, Bio9637 (51.7 days), Bio9681 (48.5 days), EH2236 (47.3 days), AH1317 (46.8 days) were late in silking. The days to 50% silking was early in humid conditions (43.6 days) as compared to in semi-arid conditions (50.2 days). The above findings were also supported by Dhaka *et al*. (2014) and Arya *et al*. (2016) in maize.

Days to 75% husk drying

In humid conditions, Vivek Hybrid 43 (73.0 days), Vivek Hybrid 21 (74.0 days), Prakash (77.7 days) were early in days to 75% husk drying. However, Bio9637 (96.7 days), AH1317 (83.0 days), EH2236 (81.7 days), Bio9681 (80.7 days) were late in 75% husk drying. In semi-arid conditions, Vivek Hybrid 43 (80.3 days), Vivek Hybrid 21 (83.7 days), Bio9637 (83.7 days) were early in days to 75% husk drying. However, EH2236 (87.3 days), AH1317 (85.0 days), Prakash (84.3 days), Bio9681 (84.0 days) were late in 75% husk drying. Likewise, on average basis, the hybrid, Vivek Hybrid 43 (76.65 days) was earliest in 75% husk drying and followed by Vivek Hybrid 21 (78.85 days), Prakash (81.0 days), Bio9681 (82.35 days). However, Bio9637 (90.2 days), AH1317 (84.0 days), EH2236 (84.5 days) were late in 75% husk drying. The days to 75% husk drying were early in humid conditions (83.6 days) as compared to in semi-arid conditions (96.9 days). Above results were also supported by Arya *et al*. (2015) and Arya *et al*. (2016) in maize.

Plant height

The mean performance (Table 1) indicated that in semi-arid conditions, Bio9681 (236.5 cm) was tallest and significantly superior over the check and other hybrids, which was followed Prakash (223.9cm), EH2236 (215.5 cm), Bio9637 (205.0 cm) AH1317 (201.4 cm). However, Vivek Hybrid 43 (182.4cm), Vivek Hybrid 21 (189.6 cm) were short in stature. Likewise, in humid conditions, Bio9637 (210.0 cm), Bio9681 (170.0 cm), Prakash (170.0 cm) were tall in plant height. However, AH1317 (130.0 cm), Vivek Hybrid 43 (143.3 cm), Vivek Hybrid 21 (156.7 cm), EH2236 (161.7 cm) were short in stature. But, on average basis, Bio9637 (207.5 cm), Bio9681 (203.25 cm), Prakash (196.95 cm), EH2236 (188.6 cm) were tall in plant height. However, Vivek Hybrid 43 (162.85 cm), AH1317 (165.7 cm), Vivek Hybrid 21 (173.15 cm) were short in stature. Similar findings were also reported in maize by Dhaka *et al.* (2014), Suthar *et al.* (2012 and 2014) and Arya *et al*. (2016). The plant height was more in humid conditions (203.4 cm) as compared to in semi-arid conditions (194.5 cm). Favourable environmental and soil conditions are responsible for better growth of plant under humid conditions.

Ear placement height

The perusal of results on mean performance revealed that in semi-arid conditions, ear placement

height was high for Prakash (103.9 cm), and followed by Bio9637 (99.0 cm), Bio9681 (93.9 cm), EH2236 (93.6 cm), AH1317 (90.3 cm) Vivek Hybrid 43 (75.7 cm), Vivek Hybrid 21 (74.0 cm). Likewise, in humid conditions, ear placement height was high for Bio9637 (121.7 cm), and followed by Prakash (93.3 cm), EH2236 (81.7 cm), Bio9681 (80.0 cm), AH1317 (65.0 cm), Vivek Hybrid 21 (51.7 cm), Vivek Hybrid 43 (66.7 cm). Moreover, on pooled basis, ear placement height was highest for Bio9637 (110.35 cm), and followed by Prakash (98.6 cm), EH2236 (87.65 cm), Bio9681 (86.95 cm), AH1317 (77.65 cm) Vivek Hybrid 43 (71.2 cm), Vivek Hybrid 21 (62.85 cm). The ear placement height was more in humid conditions (104.8 cm) as compared to semi-arid conditions (88.1 cm). Similar findings were also reported in maize by Arya *et al*. (2015). In humid conditions, higher ear placement height may be due to fast growth rate of plants in response to more availability of soil moisture and nutrients accompanying favourable environment conditions.

Conclusions

It was concluded from the present study that the hybrid Vivek Hybrid 43 with an average yield 5012.0 kg/ha was the highest in grain yield production, shortest in plant height with an average 162.85 cm as well as very low in ear placement height (71.2 cm). Moreover, it was also goo d in crop plant stand as well as in grain shelling (%). In addition to this, Vivek Hybrid 43 was also earliest in silking (44.2 days), pollen shedding (42.15 days) and 75% husk drying (76.65 days). All the maize hybrids produced more grain yield in humid conditions, as it has more fertile soil and favourable environmental conditions.

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Table 1. Mean Performance of extra-early maturing hybrids of maize under different agro-climatic conditions of Haryana.

Hybrids	Grain yield (kg/ha)			Grain shelling (%)			Plant stand (000/ha)			Days to 50% pollen shedding		
	Karnal	Hisar	Mean	Karnal	Hisar	Mean	Karnal	Hisar	Mean	Karnal	Hisar	Mean
AH1317	2972	4091	3531.5	79.7	81.3	80.50	63.9	61.4	62.65	46.3	44.0	45.15
EH2236	4142	3830	3986.0	82.3	84.9	83.60	63.3	61.1	62.20	47.0	44.0	45.50
Bio9637	5243	2990	4116.5	80.0	83.5	81.75	62.2	60.8	61.50	52.3	47.7	50.00
Bio9681	3694	2908	3301.0	79.7	84.6	82.15	62.2	61.4	61.80	49.0	45.0	47.00
Prakash	3644	5017	4330.5	81.3	85.7	83.50	63.1	60.8	61.95	46.0	38.7	42.35
Vivek Hybrid 21	4631	4294	4462.5	81.3	85.1	83.20	61.9	60.8	61.35	48.3	39.0	43.65
Vivek Hybrid 43	5047	4977	5012.0	80.6	85.1	82.85	63.3	60.3	61.80	46.0	38.3	42.15
Mean	**4196**	**4015**	**4105.5**	**80.7**	**84.3**	**82.50**	**62.9**	**61.0**	**61.89**	**47.8**	**42.4**	**45.10**
CD (5%)	197	481		0.43	2.1		1.44	1.69		1.13	2.84	
CV(%)	2.61	6.66		0.3	1.4		1.29	1.56		1.33	3.76	

Hybrids	Days to 50% silking			Days to 75% dry husk			Plant height (cm)			Ear placement height (cm)		
	Karnal	Hisar	Mean	Karnal	Hisar	Mean	Karnal	Hisar	Mean	Karnal	Hisar	Mean
AH1317	48.3	45.3	46.80	83.0	85.0	84.00	130.0	201.4	165.70	65.0	90.3	77.65
EH2236	49.3	45.3	47.30	81.7	87.3	84.50	161.7	215.5	188.60	81.7	93.6	87.65
Bio9637	54.7	48.7	51.70	96.7	83.7	90.20	210.0	205.0	207.50	121.7	99.0	110.35
Bio9681	51.0	46.0	48.50	80.7	84.0	82.35	170.0	236.5	203.25	80.0	93.9	86.95
Prakash	49.3	40.0	44.65	77.7	84.3	81.00	170.0	223.9	196.95	93.3	103.9	98.60
Vivek Hybrid 21	50.3	40.0	45.15	74.0	83.7	78.85	156.7	189.6	173.15	51.7	74.0	62.85
Vivek Hybrid 43	48.7	39.7	44.20	73.0	80.3	76.65	143.3	182.4	162.85	66.7	75.7	71.20
Mean	**50.2**	**43.6**	**46.90**	**79.5**	**84.0**	**81.75**	**163.1**	**207.7**	**185.40**	**80.0**	**90.0**	**85.00**
CD (5%)	0.76	2.86		1.65	3.3		6.95	7.65		4.48	9.06	
CV(%)	0.85	3.69		1.16	2.21		2.4	2.07		3.15	5.66	

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First Report of Yellow Dwarf Viruses (YDVs) in the Rice Fields in the Trakya Region of Turkey

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ABSTRACT

Yellow dwarf viruses (YDVs) are responsible for the economically significant disease that affects cereal crops worldwide, reducing harvested yield and quality of grains. These virus diseases on cereals have been prevailed and caused yellowing, dwarfing, reddening, and the reduction of grain yield on cultivated cereals since 1999 in the Trakya region of Turkey. This study was conducted to investigate the presence of YDVs on rice and competitive weeds as barnyard grass *Echinochloa crusgalli* (L.) P. Beauv, Johnson grass *Sorghum halepense* (L.) Pers. and common reed *Phragmites australis* (Cav.) Trin ex. Steudel in the Trakya region of Turkey. For this purpose, 120 symptomatic rice leaves and 18 weed leaf samples were collected from the rice fields in Trakya. A total of 138 symptomatic leaf samples were tested by DAS-ELISA and RT-PCR methods for the diagnoses of *Barley yellow dwarf virus*-PAV (BYDV-PAV), *Barley yellow dwarf virus*-MAV (BYDV-MAV) and *Cereal yellow dwarf virus*-RPV (CYDV-RPV). The screening test results revealed that 26 out of 138 leaf samples had CYDV-RPV, 5 of them infected with BYDV-PAV, and 10 leaf samples were found infected with a mixture of CYDV-RPV+BYDV-PAV. Thus, 41 out of 138 leaf samples at the rate, 30% were found infected with BYDV-PAV and CYDV-RPV. None of the samples had BYDV-MAV. To our knowledge, this is the first report of BYDV-PAV and CYDV-RPV in the most important rice-growing areas of Turkey

Keywords: Rice, weed, YDVs, CYDV-RPV, BYDV-PAV

Introduction

Rice (*Oryza sativa* L.) is one of the most important cereal crops as a source of human nourishment. Peoples of Far-East and South-Eastern Asian countries consume rice as basic food. Among them, the People's Republic of China is an important rice producer worldwide, with 212 million tons of annual yield (Anonymous 2018a). Rice is grown as a semi-aquatic cereal field crop in Turkey, having an annual yield of 940000 tons, being 460726 tons of it, at the rate of 49.01% produced in Edirne, Kırklareli and Tekirdağ provinces in the Trakya region of Turkey (Anonymous 2018b). Although, rice is susceptible to 36 fungal, 12 bacterial, 18 viral, 2 phytoplasma diseases, and 6 nematode species have been found harmful to rice crops in the Tropical Far East, South East Asian, and African countries (Webster and Gunnell 1992). Among them, rice blast disease caused by *Pyricularia grisea* (Cooke) Sacc. (Syn. *Pyricularia oryzae* Cavara; teleomorph: *Magnaporthe grisea*) has been considered the most destructive fungal disease widespread worldwide in all those rice-growing countries and Turkey (Bonman, 1992). White tip nematode *Aphelenchoides besseyi* Christie occurred worldwide on rice and also was diagnosed by Öztürk and Enneli (1997) in the rice fields of the Trakya region in 1995. In European, rice-growing areas, Osler *et al*. (1980) reported that rice Giallume disease in Italy caused a strain of *Barley yellow dwarf virus* (BYDV), on its weed host *Leersia oryzoides*

was the over-seasoning host of BYDV. Following, Osler *et al*. (1984) observed severe yellow dwarf virus (YDV) infections caused by rice Giallume strain and their aphid vectors in rice fields of Italy. Similarly, Medina *et al*. (1986) identified 8 out of 30 aphid species as the vectors of YDVs at the important rice-growing regions of Valencia and La Albufera in Spain. Later, Jorda *et al*. (1987) identified BYDV to be a disease caused 'enjorat' disease in the rice areas in Spain and determined preventing by decreasing the effectiveness of *Rhopalosiphum padi.* Subsequently, Belli *et al*. (1990) determined the disease cycle, with their aphid vectors in Italy and the occurrence order of YDVs on cereal species, beginning with winter barley, spring wheat, rice, corn and oat in the annual disease cycle. YDV disease is classified in the genera *Luteovirus* and *Polerovirus*. *Barley yellow dwarf virus* (BYDV)-PAV, BYDV-PAS, BYDV-MAV, BYDV-GAV, BYDV-SGV is included in the genus *Luteovirus.* Members of the genus *Polerovirus* comprise *Cereal yellow dwarf virus* (CYDV)-RPV, CYDV-RPS, Wheat yellow dwarf virus-GPV (WYDV-GPV), and Maize yellow dwarf virus-RMV (MYDV-RMV) (Miller and Rasochová 1997; Chay *et al*.1996, Ueng *et al*. 1992; Jin *et al*.2004; Liu *et al*. 2007; Rochow and Miller 1971; Mayo 2002; Zhang *et al*. 2009; Kruger *et al*. 2013). YDVs have isometric particles of 25-30 nm in diameter and ss(+) RNA genome of approximately 5600 nucleotides (Vincent *et al*.1991). These viruses are phloem-limited and are transmitted in a persistent circulative manner by over 25 aphid vectors. (Smith and Plumb1981; Halbert and Voegtlin 1995). For the first time in Turkey, Bremer and Raatikainen (1975) observed and reported sporadic YDV diseases with their aphid vectors on cereals. After that, epidemic of YDV diseases and wheat dwarf infections on winter bread wheat (*Triticum aestivum* L.) and other cereals were observed in Trakya by İlbağı (2003) and İlbağı *et al*. (2005). Subsequently, İlbağı (2006) identified Common reed (*Phragmites communis* Trin) as an over-summering and over-wintering host of YDVs. As the most critical YDV species that BYDV-PAV was identified in maize fields individually and had the coinfection with *Maize dwarf mosaic virus* (MDMV), *Sugarcane mosaic virus* (SCMV) and *Johnson grass mosaic virus* (JGMV) species in the Trakya region (İlbağı *et al*. 2006). In addition to major small grains, canary seed (*Phalaris canariensis* L.) was also found to be an extremely susceptible host of YDVs in canary seed fields of Tekirdag province (İlbağı *et al*. 2008). Poaceae weed host species of YDVs and their aphid vectors were determined and identified in and surroundings of cereal fields in the Trakya Region (İlbağı *et al*. 2011; İlbağı *et al*. 2013; İlbağı *et al*. 2018). Up to now, another virus disease on rice as *Rice ragged stand virus* (RRSV) and *Rice yellow mottle virus* (RYMV) were identified in the rice fields of Edirne province by Köklü and Yilmaz (2004). Additionally, Moletti *et al*. (1990) determined the destructive effects of Rice giallum virus diseases on rice crop development stages, like yield loss and yield quality reductions on 11 Italian rice cultivars. *Rice ragged stand virus* (RRSV) causes epidemics on rice paddies in Far-East countries, transmitted by a brown planthopper *Nilaparvata lugens* (Stal) in which virus circulates and propagate. Another one is *Rice yellow mottle virus* (RYMV) that occurs in African countries and transmitted by a Chrysomelidae species *Sesselia pusilla* Gerstaecker none persistently (Hibino 1992).

This present investigation was aimed to determine the infections of YDVs on rice and some weeds as potential reservoir inoculum sources in the border of the rice fields, which cause yellowing, redness, stripe mosaic, browning of leaves, dwarfing and stunting symptoms.

Materials and Methods

Survey studies and sampling: Survey studies were carried out in 17 rice growing fields of 7 districts in Edirne, Kırklareli, and Tekirdağ provinces of the Trakya region. Characteristic YDV disease symptoms such as yellowing, dwarfing, and redness were observed in the rice fields. Similar symptoms were observed rarely on Barnyard grass (*Echinochloa crusgalli (*L.) P. Beauv), Johnson grass (*Sorghum halepense* L., Pers.) and Common reed (*Phragmites austrialis* (Cav.) Trin ex. Steudel) weed samples during the surveys. 63 symptomatic rice leaf samples from Edirne, 28 leaf samples from Kırklareli, 29 leaf samples from Tekirdag, totally 120 symptomatic rice leaf samples were collected as plant materials of this study. Separately, 18 weed leaf samples were collected from the rice-growing areas of Trakya. A total of 138 leaf samples composed of study plant materials for the identifications of YDVs.

Serological test: 138 leaf samples were tested with polyclonal antibodies (manufactured by AGDIA Inc.; Elkhart IN, USA) for the presence *Barley yellow dwarf virus*-PAV (BYDV-PAV), *Barley yellow* dwarf *virus*-MAV (BYDV-MAV) and *Cereal yellow dwarf virus*-RPV(CYDV-RPV) by employing Double Antibody Sandwich Enzyme-Linked Immunosorbent Assays (DAS-ELISA) as described by Clark and Adams (1977). Optical densities at 405 nm (OD_{405}) were measured with an ELISA reader (Thermo Fischer

Scientific Instruments Co Ltd.Waltham, MA USA) a positive reaction was recorded when the OD_{405} of a sample was twice that given by sample from a healthy control plant.

Nucleic acid isolation and cDNA synthesis: The symptomatic leaf samples gave a positive reaction with the Enzyme-Linked ImmunoSorbent Assay (ELISA) test were verified by Reverse Transcription Polymerase Chain Reaction (RT-PCR) test. These symptomatic leaf samples to investigate YDVs; BYDV-PAV, BYDV-MAV and CYDV-RPV were subjected to the isolation of the viral nucleic acids by employing the total nucleic acid extraction method described by Falke *et al*. (2000). First-strand cDNA was synthesized from total isolated RNA by using RevertAidTM First Strand cDNA Kit (Fermentas; Vilnius, Lithuania). In each reaction, 0.5 µg RNA sample and 20 pmol of reverse complementary primer pair of BYDV-PAV, BYDV-MAV and CYDV-RPV were used and processed according to the manufacturer's instructions.

RT-PCR amplifications: A total of 41 symptomatic samples were tested by RT-PCR. Lu1 and Lu4 specific primers of *Luteoviruses* (Robertson *et al*. 1991) were used for the identification of BYDV-PAV, while specific primers were used for BYDV-MAV and CYDV-RPV (Deb and Anderson 2007). The PCR reaction mixture contained 2 µl cDNA, 10 mM dNTPs, 10 µM each of forward and reverse primers, 10x PCR buffer, $MgCl_2$ (25 mM), 2.5 U of Taq DNA polymerase (Fermentas; Vilnius, Lithuania) and RNase free water in a 25 µl reaction volume. PCR conditions were optimized for each virus against a range of concentrations and annealing and extension temperatures. The PCR cycling conditions for BYDV-PAV consisted of an initial denaturation at 94°C for 2 min, followed by 40 cycles at 94°C for 1 min, 43°C for 1 min, 72°C for 1 min. and the final extension step at 72°C for 10 min. The thermal cycling conditions for BYDV-MAV consisted of 40 cycles at 95°C for 30 sec, 55°C for 1 min, 72°C for 1 min and the final extension step at 72°C for 10 min. Cycling conditions of CYDV-RPV comprised an initial denaturation at 94°C for 2 min, followed by 40 cycles at 94°C for 30 sec, 60°C for 45 sec, 72°C for 1 min and the final extension step at 72°C for 10 min in Thermal cycler. The obtained PCR products were analyzed by electrophoresis in 1.5% agarose gel, stained with EtBr and viewed under UV illumination in a gel documentation system (Vilber Lourmet; Marne La Vallee Cedex 1, France).

Results and Discussion

In the rice-growing areas of the Trakya region are taken part of the large rice fields and small rice paddies side by side. Rice cultivation is a monoculture type without rotation with any other field crop. During the surveys in rice fields and paddies, virus infections have been observed as patches as well as the whole surface area of the rice fields. Moreover, infected rice plants exhibited color changes of leaves, stems from green to yellowing, and got into orange color. Furthermore, infected individual rice plants displayed erected stems and dwarfing, stripe mosaic, yellow main-vein, and necrotic browning leaves similar to Hibino's (1992) description. Also, İlbağı (2006) and İlbağı *et al*. (2013) reported that stripe mosaic, yellowing on the central vein and necrotic symptoms have been observed on common reed (*P. austrialis*), Johnson grass (*E. crusgalli*) and barnyard grass (*S. halepense*). These findings were the consensus on our results. Osler *et al*. (1984) cited that early infection of seedlings and the severe disease usually destroy rice plants. Because of YDVs infections, the reduced number of tillers, and the reduction of grain yield have occurred from 5% to 100%. The screening test results in this present study revealed that 23 out of 120 symptomatic rice leaf samples were infected with CYDV-RPV. Symptomatic 4 other samples had BYDV-PAV, and 9 of them were found infected with a mixture of CYDV-RPV+BYDV-PAV. The tested 18 symptomatic weed leaf samples revealed that 5 of them infected with the same YDVs. As a result, 26 out of 138 leaf samples were found infected with CYDV-RPV at the rate of 18.94%. Symptomatic 5 leaf samples at a rate of 3.72% had BYDV-PAV. The other 10 symptomatic leaf samples had coinfection with CYDV-RPV+BYDV-PAV at the rate of 7.34%. None of the tested leaf samples had BYDV-MAV. Thus, 41 out of 138 symptomatic leaf samples were found infected with YDVs at the rate of 30%, including BYDV-PAV and CYDV-RPV. Our results confirmed the previous reports of Osler *et al*. (1980), Osler *et al*. (1984) in Italy, as well as the reports of Medina *et al*. (1986) and Jorda *et al*. (1987) in Spain. By evaluating 119 articles about BYDVs, Miller and Rasochova (1997) reviewed that YDVs occasionally infect warm-season cereal species of rice and maize, and their epidemics occur rarely. Global climatic changes, however, cause a kind of variation on the population dynamics of vectors. Accordingly, YDVs may occur wherever their cool-season and warm-season cereal hosts and their Poaceae weed host are present. Otherwise, tropical rice diseases of Rice ragged stand virus (RRSV) and Rice yellow mottle virus (RYMV) defined by Hibino's (1992), however, occurrence in rice fields of Edirne in Turkey reported by Köklü

and Yilmaz (2004) could not be explained. Mainly, YDVs and their epidemic infections on cereals have been reported in the Trakya Region by İlbağı (2003) and İlbağı *et al*. (2005). Besides rice leaf samples, 3 out of 18 weed samples had CYDV-RPV, only one of them was positive with BYDV-PAV, and one weed sample was found infected with the mixture of both virus species of YDVs (İlbağı, 2013). Thus, efficient control measures of those YDV infections of winter bread wheat and other cereals were established by İlbağı (2016). Those control measures include the use of tolerant cultivars, usage of selective herbicides for weed hosts control of YDVs, usage of imidacloprid insecticide for seed dressing also suggested like Royer *et al*. (2005) before sowing and the timing of sowing date. YDVs cause infections on all of the cereal species, including wheat, barley, rye, maize, oat, triticale, bird seed in Turkey as reported by İlbağı (2003), İlbağı *et al*. (2005), İlbağı *et al*. (2006), İlbağı *et al*. (2008). The results of this study revealed that rice is a new cereal host of YDVs in Turkey. To our knowledge, this is the first report of YDVs for the present on rice in Turkey.

Table 1. The screening test results of YDVs on rice and three species of weeds in rice growing provinces of Trakya region.

Name of Host Plants	**Number of Plant Samples**	**Number of Virus Infected Samples**				**Total Number of Infected Samples**
		RPV	**PAV**	**MAV**	**RPV+PAV**	
Rice (*Oryza sativa*)	120	23	4	-	9	36
J. grass (*S. halepanse*)	10	2	-	-	-	2
B. grass (*E. crusgalli*)	2	1	-	-	-	1
C. reed (*P. austrialis*)	6	-	1	-	1	2
Total	**138**	**26**	**5**	**-**	**10**	**41**
Rate of infections (%)	**-**	18.84	3.62	-	7.25	29.71

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Research Article

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A Comparison of Phenotypic Root Characteristics in Local Eggplant Genotypes (*Solanum melongena* L.) Infected and Non-Infected with *Fusarium oxysporum* f. sp. *melongenae*

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ABSTRACT

The eggplant (*Solanum melongena* L.) is an important vegetable species cultivated under openfield and greenhouse conditions in Turkey. In recent years, due to fungal disease in eggplant growing areas, yield quantity and fruit quality problems have been encountered. One of the most effective precautions against disease is to determine the genetic materials that are resistant or tolerant to disease and evaluate them in the plant breeding programs. The number of breeding studies for forming a strong root system in varieties of eggplants is very limited in Turkey. The most important criteria that affect the performance in varieties of eggplant are the root structure and the ability of development under stress conditions. This study investigated 66 local eggplant genotypes against infection by *Fusarium oxysporum* f. sp. *melongenae*. Plants inoculated with *Fusarium oxysporum* f. sp. *melongenae* and non-inoculated (control) plants were subjected to a separate statistical analysis. The Karabey F_1 was used as the positive control variety. The root system architectures parameters (total root length, the root surface area, the root volume, and the root diameter) were determined using the WinRHIZO program. The total root length ranged from 14.57 cm (G43-3) to 787.09 cm (G91), the root surface area ranged from 5.20 cm^2 (G42) to 457.53 cm^2 (G91), the root volume ranged from 0.10 cm^3 (G42) to 26.22 cm^3 (G128), and the root dimeter changed 0.60 mm (G144) to 5.87 mm (G152). When all the characteristics that constituted the root canopy were evaluated together, the root traits of genotype G91 and genotype G113 were found to be stronger and superior compared to the other local eggplant genotypes.

Keywords: Eggplant, *Fusarium* wilt, root system architecture, resistance, Turkey

Introduction

There are approximately 2300 species in the *Solanaceae* family. Half of these species are classified in the genus *Solanum*. This family consists of many cultured species that differ morphologically from each other (Sekara *et al*. 2007). The origin of eggplant is in the Southeast Asia (India and Burma countries). It was first brought to the Mediterranean basin by the Arabs. The first records about eggplants in Europe were found in the 15th century (Kalloo 1993; Çakır *et al*. 2017). The transition of eggplants to the new world was carried out by the Spanish. It was spread to Europe through the Balkan countries by Turks. It is reported that eggplants reached Anatolia in the late 16th century and early 17th century (Vural *et al*. 2000; Çakır *et al*. 2017).

Local genetic resources are very important resources for plant breeders in the development of new varieties with high yield and superior qualities in agricultural production (Balkaya and Yanmaz 2001; Karaağaç and Balkaya 2017; Çakır *et al*. 2019).They have an irreplaceable value and importance for plant breeding studies because they include both cultivated

plants and their wild relatives (Engels *et al*. 1995). Local genetic resources are unique sources for a variety of breeding programs due to their adaptability to different ecologies, their resistance to diseases and pests, and the demanded fruit quality characteristics. Genetic diversity has occurred over time and landraces with different qualities have developed in the major eggplant produce countries (Çakır 2018; Çakır *et al*. 2019).

Diseases and pests are the major problems encountered in eggplant cultivation. Breeding purposes for the developing new qualified varieties can generally be listed as featuring high yield, fruit quality, earliness, and resistance to biotic and abiotic stress factors in eggplant cultivation. Diseases such as *Fusarium* wilt, *Verticillium* wilt and root knot nematode pest affect the eggplant cultivation economically. In eggplant cultivation, approximately 50% of the yield values were occurred in areas contaminated with *Fusarium oxysporum* f. sp. *melongenae* (FOMG) that causes *Fusarium* wilt in Turkey (Altınok 2005). To combat *Fusarium* wilt, it is important to use disease resistant varieties and to cultivate in soil that is not infected with the disease. Studies conducted in the fight against *Fusairum* wilt have reported that developing resistant varieties will provide quality products and significantly reduce yield losses (Miller *et al*. 1996; Rizza *et al*. 2002). The number of eggplant varieties resistant to *Fusarium* wilt are almost available in Turkey (Kandemir *et al*. 2016).

Tolerance to edaphic stress has been linked to root system morphology (Suchoff *et al*. 2017). The most important criteria affecting variety performance are root canopy and rooting ability under stress conditions. The ability of rooting to directly take in water and plant nutrients affects the performance of the parts above ground. Root structures need to be examined closer and should be selected for a variety of breeding programs (Schiefeibein and Benfey 1991; Koevoets *et al*. 2016). However, it is quite difficult to examine the root structure, which is inherently underground, compared to the organs above ground. So, the number of selection breeding studies carried out according to the phenotypic features of the root is very limited (Schwarz *et al*. 2010; Suchoff *et al*. 2017; Sarıbaş *et al*. 2019). In recent years, detailed investigations about root structures have been made possible using digital imaging systems (Peaz-Garcia *et al*. 2015, Suchoff *et al*. 2017; Sarıbaş, 2019; Karaağaç *et al*. 2020). Phenotypic root selection study is a new and topical subject in Turkey. In this study, the aim was to investigate the phenotypic root structures of local eggplant genetic resources that have different fruit characteristics and to compare the factors that compose rooting architectures in plants infected with *F. oxysporum* f. sp. *melongenae* and in non-infected plants.

Materials and Methods

Materials: In this study, a total of 66 eggplant genotypes were collected from different regions of Turkey and were used as genetic materials. Also, the Karabey F_1 eggplant variety was used as a positive control in disease testing trials. FOM-10 isolate from *F. oxysporum* f. sp. *melongenae* used in this study was obtained from Dr. H. Handan Altınok.

Growth Condition: This study was carried out in the Samsun province in 2017. The seeds of all eggplant genotypes were sown in different stages on 26 March 2016, 19 August 2016 and 03 March 2017 in the greenhouse belonging to the Ondokuz Mayıs University, Faculty of Agriculture. The growing medium was prepared as a peat: per lite mixture in a 3:1 ratio. Forty seedlings for each eggplant genotypes were grown at the 4 to 5 true leaf stage (approximately 40 days) in the greenhouse.

Determination of root characteristics in eggplant genotypes infected and non-infected with *Fusarium oxysporum* f. sp. *melongenae*: The reactions against *F. oxysporum* f. sp. *melongenae* of the 66 eggplant genotypes and the Karabey F_1 variety, which is known to be sensitive to Fusarium wilt (positive control), were determined *in vivo*. For disease testing, the root dipping method was applied to the eggplant seedlings at the 4 to 5 true leaf stage (Biles and Martyn 1989). Firstly, the roots of the eggplant seedlings were washed in tap water, and then any apparent scar tissue was opened by gently shaving off the root tips with clean scissors. After that, the roots were immersed in the prepared conidia suspension (1×10^6 conidia mL^{-1}) and kept for ten minutes (Altınok 2005). The control plants were also kept in sterile distilled water for the same period. After inoculation, the eggplant seedlings were planted in plastic pots (18 × 16 cm diameter) containing a mixture of peat: perlite (3: 1, v/v) with one seedling per pot. The experiment on rooting levels in eggplant genotypes was carried out using three replicates with ten plants per replicate in the randomized block design. Then, the eggplants were grown at 25 ± 1°C for 4 weeks in controlled growth chambers.

The WinRHIZO root analysis program (Regent Instrument Inc. Canada) was used to examine the root system architectures of the eggplants. In this study, plants were gently excavated from the growing medium at the end of the 30th day. Then the root system was freed. All roots were carefully washed and dried with a paper. Roots were placed in the tray and gently

positioned with no overlapping roots to allow for more uniform scanning. Scans were done in gray scale at 800 dots per inch to increase resolution of fine roots (Suchoff *et al*. 2017). All data were transferred to the computer in 3D. As a result of the roots canning performed using the WinRHIZO program, the following root parameters, which reveal the root system architectures, were determined according to Suchoff *et al*. (2017) and Sarıbaş *et al*. (2019).

The total lengths of all roots (cm), including hairy roots in capillary form, were measured. All roots were classified as hairy (1 mm>), medium (1 mm≤D≤2 mm) and thick (2 mm<) roots and length per diameter class were calculated proportionally. Average root diameter (mm) was calculated by examining all root extensions individually. In addition, root surface area (cm^2) and root volume (cm^3) values were determined using the WinRHIZO program. Following scanning, roots were dried at 70°C for 48 hours; it was continued until the samples reached a constant value. Then, the dry weight of the root was determined by weighing on a precision scale (0.001 g) (Karaağaç 2013).

Data Analysis: The results of the study were first tested for normality to determine their conformity to a normal distribution. Variance analysis was carried out using the SAS-JMP 5.01 statistical package program to determine the statistical significance of the investigated root system criteria and differences among eggplant genotypes. Further, Arcsin transformation was applied to the value obtained. Moreover, correlation analysis was used to determine whether there was a statistical relationship between the investigated root characteristics.

Results and Discussion

Total root lengths, particularly in the deeper soil profile, can improve water acquisition (Comas *et al*. 2013; Suchoff *et al*. 2017). The total root length values of eggplant genotypes infected with *F. oxysporum* f. sp. *melongenae* were varied from 14.57 cm (G43-3) to 787.09 cm (G91). Among all the genotypes, the genotypes G91 (787.09 cm), and G113 (647.20 cm) determined the highest root length values (Table 1). The root length of the Karabey F_1 variety was measured to be 116.02 cm. The highest root length value was determined to be 1048.18 cm (G4-1) and the lowest root length value was determined to be 159.40 cm (G49) in the control treatment. The difference in root length values between treatments was at least 2.98 cm (G113), 16.24 cm (G91) and 66.74 cm (G128). The difference in this overlap in the genotypes that are prominent in the disease experiment supported the accuracy of the study results (Table 1). Sarıbaş (2019) determined that total root values were ranged from 1299 to 4322 cm among eggplant rootstock hybrids (*S. melongena x S.aethiopicum*). In the other study, the root characteristics of the *C. baccatum* and *C. chinense* species were found to be stronger and superior than the C. *annuum* species. *C. chinense* in terms of root length and root surface area and *C. baccatum* in terms of root volume and dry weight were more prominent (Karaağaç *et al*. 2020).

The ratio of roots with a diameter of less than 1 mm to total root lengths in plants is an important selection criterion in the resistant variety of breeding programs (Sarıbaş *et al*. 2019). In this study, it has been determined that there are statistically significant differences between the root rate values less than 1 mm in eggplant genotypes. Pereira-Dias *et al*. (2018) reported that nutrient intake in roots smaller than 1 mm in grafted pepper plants was 4 to 5 times more than roots larger than 1 mm. Most of the root length proportional diameter values of eggplant genotypes (more than 70%) infected with FOM-10 isolate consisted of roots less than 1 mm in diameter (Table 2). Further, it was determined that the root length and proportional diameter values of the eggplant genotypes were mostly in those genotypes ranging from 1 to 2 mm in the 10 to 15% ratios for control treatment (Table 3). Among eggplant genotypes, the rates of genotypes with root diameter values greater than 2 mm were found to be from 5 to 10% (Table 4). Sarıbaş *et al*. (2019) were determined that proportional diameter values of the eggplant genotypes consisted of roots less than 1 mm in diameter changed from 64% to 82%.

The average root diameter value is another important indicator of the hairy root tendency. A low average root diameter increases the effects of the absorption ability of the root (Sarıbaş, 2019; Karaağaç *et al*. 2020). Significantly differences were found between the average root diameter values in eggplant genotypes treated with *F.oxysporum* f. sp. *melongenae* according to this study finding. The highest average root diameter value was measured 2.17 mm (G177) among the infected genotypes. The lowest average root diameter value was determined 0.60 mm (G144). When the average root diameter values were examined in the control plants, the highest value was determined 5.87 mm (G152), and the lowest value was measured 1.2 mm (G8) (Table 5). A reduction in root diameter has been also observed in response to low P concentrations and salinity (Zobel *et al*. 2007; Lovelli *et al*. 2012; Suchoff *et al*. 2017). Sarıbaş *et al*. (2019) determined that the root diameter value in the eggplant rootstock hybrids. Researchers found a distribution ranging from 1.1 mm to 3.2 mm for root diameter trait. Besides, root

diameter vary according to plant species. Suchoff *et al*. (2017) informed that HN-1088' tomato rootstock had the widest average root diameter (0.37 mm) compared with all other cultivars. The difference in terms of root volume with this literature was caused by the genotype effect. Karaağaç *et al*. (2020) determined the average root diameter of *C. annuum* as 2.45 mm, *C. baccatum* as 3.18 mm and *C. chinense* as 2.80 mm. For tomato rootstock root systems, two commercial rootstocks ('Beaufort' and 'Heman') indicated differences in root density but not of average root diameter (Oztekin *et al*. 2009).

Excessive root surface area is an important factor that increases the water and nutrient uptake capacity of the roots (Sarıbaş, 2019). It has been determined that there are very important differences between infected plants and control plants in terms of root surface area values. When the root surface areas of the eggplant genotypes infected with *Fusarium oxysporum* f. sp. *melongenae* were examined, the highest value was determined in the G91 genotype at 457.53 cm^2. The lowest value was found in the G42 genotype at 5.20 cm^2 (Table 6). Genotypes with the highest root surface area were also determined to exhibit a high resistance to disease. The root surface areas of G113 genotype, which was determined to be highly resistant, and G128 which was determined to be tolerant, were measured at 415.72 and 367.50 cm^2, respectively. When non-infected genotypes were evaluated, the highest value was 1142.59 cm^2 (G152) and the lowest value was 164.23 cm^2 (G2) (Table 6). Kakita . (2015) reported on tomatoes and Bertucci *et al*. (2018) mentioned on watermelons in their respective studies tha trootstocks have higher root surface areas and this increased rate varies according to the rootstock used.

One of the important criteria in terms of root system canopy parameters is the root volume (Karaağaç *et al*. 2020). This criterion is an important factor on the level of resistance to diseases. In this study, root volumes of disease-infected eggplant genotypes were determined at their lowest to be 0.10 cm^3 (G42) and at their highest 26.22 cm^3 (G128). It was also determined that there were statistically significant differences between treatments and genotypes in terms of root volume values.When the root volumes of plants not infected (control) treatment were examined, the lowest root volume was 7.41 cm^3 (genotype G8) and the highest was 66.71 cm^3 (genotype G152). The root volumes of the control plants of promising tolerant eggplant genotypes G91, G113 and G128 were determined 24.17, 41.21 and 40.93 cm^3, respectively (Table 7). Sarıbaş *et al.* (2019) found that the root volume of eggplant rootstocks varied from 40.5 to 96.8 cm^3 in their study. They also reported that the root volume was directly related to the root diameter. When the percentage change rates in the root volumes of eggplant genotypes resistant to the disease were examined, the least affected genotypes were determined G177-1 (26.59%), G128 (34.80%), G91 (41.29%) and G113 (47.94%). The rate of change in the Karabey F_1 variety used as the positive control in the study was found to be 96.88%. The difference between the promising resistant genotypes and the root volumes of the control variety (70.29%) was an important finding that showed efficient of virulent the FOM-10 isolate used in the study.

When the dry weight values of the roots of the genotypes infected with *F. oxysporum* f. sp. *melongenae* were analyzed, it was found that they showed statistically significant differences. When Table 8 was examined, the highest dry root weight value was found to be 0.79 g (genotype G177-1) among the infected plants. The lowest dry weight value for the roots was determined to be 0.01 g (genotype G69). When the dry weights for the roots of the genotypes that were prominent in terms of the disease test were examined, they were determined to be 0.33 g (genotype G91), 0.39 g (genotype G113) and 0.35 g (genotype G128) (Table 8). In the control treatment, the highest value was found to be 1.08 g (genotype G69), and the lowest root dry weight value was determined to be 0.11 g (genotype G33). When the percentage changes in the dry weights of the roots of the eggplant genotypes were examined, the highest ratio was determined to be 98.46% (genotype G69) (Table 9). Sarıbaş *et al.* (2019) determined that dry weight values in eggplant genotypes varied between 10.03 g and 15.13 g. In this study, the fact that the changes in the root dry weights are low in genotypes determined to be resistant showed that the plant can maintain normal photosynthesis activities despite the disease affect.

A correlation analysis was carried out to statistically reveal the relationship between the root system traits of eggplant genotypes and resistance against *Fusarium* wilt disease in this work. It was determined that there was a negative relationship between disease severity and root system characteristics (P>0.01). When the diseases severity increased, total root length, root surface area, mean root diameter and total root volume values decreased (Table 10). This result showed that the root length, root surface area, and root volume values are the most important root characteristics on the resistance level for *Fusarium* wilt disease. It was determined that there was a positive relationship between the root characteristics of the infected plants. As the root length values increased,

root surface area, root volumes and root percentage changes similarly increased. No significant statistical relationship was found between the diameter class values of root lengths and other parameters. However, a significant relationship was found between the root dry weights of the eggplant genotypes and the root weight percent changes. In accordance with these findings, it was determined that root length, root surface area and root volume values should be evaluated as important criteria in eggplant genotypes in the disease breeding programs.

Conclusions

In recent years, important problems have been encountered in terms of the annual production amount and fruit quality properties in the eggplant growing areas in Turkey due to fungal factors. *F. oxysporum* f. sp. *melongenae*, one of the soil-borne fungi plant pathogens, causes loss of yield values in eggplants, blockages in vascular bundles and wilt disease. The most effective precaution that can be taken against the diseases is to identify the genetic materials from genetic resources that have resistant or tolerant traits and evaluate them in a variety of breeding programs. Resistance eggplant varieties offer growers the ability to manage soil borne diseases in the production. This research indicates that quantifiable morphological differences exist between locale eggplant roots systems. In this study, we determined that the tolerance to *F. oxysporum* f. sp. *melongenae* disease stress has been linked to root system morphology. Some of the root system differences observed may explain the improved disesase stress tolerance provided by promising egglant genotypes. Additionally, these differences may help to explain the improved growth and eggplant production associated with qualified resistant varieties of eggplant.

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Table 1. Total root length values (cm) of eggplant genotypes infected and non-infected (control) plants by *F. oxysporum* f. sp. *melongenae*.

Genotype	Infected Plant	Control	Genotype	Infected Plant	Control
G1	144.88 d-g	530.22 b-n	G56	70.67 f-g	776.77 a-i
G2	658.62 a-b	268.96 j-n	G58	59.82 f-g	860.87 a-f
G4-1	57.42 f-g	1048.18 a	G61	58.78 f-g	503.83 b-n
G4-2	67.44 f-g	987.54 a-b	G63	68.44 f-g	319.35 h-n
G5	21.61 g	602.81 a-n	G64	97.51 d-g	881.05 a-e
G7-1	17.86 g	195.70 n	G66	135.37 d-g	664.94 a-n
G7-2	36.59 f-g	577.49 a-n	G68	93.63 d-g	710.66 a-l
G8	56.65 f-g	623.94 a-n	G69	91.72 d-g	832.87 a-g
G11-2	68.21 f-g	359.62 g-n	G73	73.91 e-g	614.40 a-n
G12	60.08 f-g	629.41 a-n	G80	83.94 d-g	535.15 b-n
G15	56.65 f-g	309.10 h-n	G88	98.29 d-g	909.40 a-d
G16	71.24 f-g	550.80 a-n	G 91	787.09 a	803.33 a-h
G20	29.85 f-g	447.87 c-n	G98	62.63 f-g	390.62 e-n
G21	112.46 d-g	911.33 a-d	G109	187.92 d-g	234.03 j-n
G22-1	56.99 f-g	771.72 a-i	G113	647.20 a-c	650.18 a-n
G22-2	99.72 d-g	717.42 a-k	G114	148.56 d-g	846.43 a-g
G23	138.03 d-g	576.27 a-n	G119	16.40 g	256.58 j-n
G33	118.40 d-g	924.00 a-d	G122	17.96 g	259.48 f-n
G35-1	533.02 a-d	873.33 a-e	G125	194.27 c-g	931.72 a-c
G36	365.84 a-g	733.64 a-j	G127	218.48 b-g	680.29 a-n
G39	75.45 d-g	523.16 b-n	G128	709.66 a	777.40 a-i
G40-1	112.45 d-g	513.52 b-n	G134	68.40 f-g	367.97 f-n
G40-2	480.24 a-f	603.20 a-n	G138	65.12 f-g	687.39 a-n
G42	21.36 g	540.06 b-n	G144	56.95 f-g	365.42 f-n
G43-1	23.43 f-g	195.70 m-n	G146	101.53 d-g	918.53 a-d
G43-2	40.42 f-g	293.71 i-n	G147	68.57 f-g	707.56 a-m
G43-3	14.57 g	278.53 i-n	G148	72.03 e-g	712.11 a-l
G45-1	41.22 f-g	282.92 i-n	G152	69.75 f-g	641.72 a-n
G45-2	31.27 f-g	216.55 l-n	G154	64.04 f-g	616.44 a-n
G47	245.93 b-g	607.46 a-n	G161	441.74 a-g	889.53 a-e
G49	27.94 f-g	159.40 k-n	G173	140.75 d-g	359.87 g-n
G53	80.59 d-g	496.69 b-n	G177-1	529.69 a-e	427.91 d-n
G55	58.52 f-g	662.65 a-n	G179	84.49 d-g	456.90 c-n
			Karabey	116.02 d-g	540.12 b-n

P>0.01

Table 2. The ratio of root length per diameter class values (D>1 mm) of eggplant genotypes infected with *F. oxysporum* f. sp. *melongenae* and non-infected (control) plants (%).

Genotype	Infected Plant	Control	Genotype	Infected Plant	Control
G1	87.15 a-e	85.46 a-j	G56	78.57 d-m	83.90 a-j
G2	77.09 e-n	70.02 i-j	G58	75.25 f-o	88.11 a-h
G4-1	78.55 d-m	92.98 a-e	G61	80.99 b-k	83.43 a-j
G4-2	77.61 e-n	78.54 c-j	G63	76.99 e-n	92.47 a-f
G5	80.35 b-l	92.22 a-f	G64	76.76 e-n	94.74 a-c
G7-1	66.26 n-p	80.02 b-j	G66	72.52 h-p	81.84 b-j
G7-2	71.35 j-p	82.85 a-j	G68	76.47 e-o	91.27 a-g
G8	80.44 b-l	84.83 a-j	G69	73.17 h-p	74.27 g-j
G11-2	73.72 g-o	75.34 f-j	G73	79.26 b-m	94.16 a-d
G12	76.18 e-o	88.84 a-h	G80	79.88 b-l	83.12 a-j
G15	72.95 h-p	86.08 a-j	G88	71.82 j-p	79.34 c-j
G16	71.52 j-p	87.83 a-h	G 91	93.69 a	88.78 a-h
G20	67.79 m-p	88.24 a-h	G98	82.09 a-k	89.09 a-h
G21	84.13 a-h	85.25 a-j	G109	75.24 f-o	84.31 a-j
G22-1	72.08 j-p	81.12 b-j	G113	80.19 b-l	77.37 c-j
G22-2	85.21 a-g	94.72 a-c	G114	71.03 j-p	96.96 a-b
G23	75.74 e-o	75.25 f-j	G119	70.43 k-p	84.35 a-j
G33	74.54 f-o	77.47 c-j	G122	81.82 b-k	76.90 d-j
G35-1	82.34 a-j	85.83 a-j	G125	75.35 f-o	78.21 c-j
G36	79.29 b-m	79.82 b-j	G127	72.27 i-p	69.07 j
G39	77.39 e-n	77.91 c-j	G128	83.94 a-i	78.88 c-j
G40-1	67.87 m-p	82.94 a-j	G134	86.24 a-f	75.64 e-j
G40-2	79.41 b-m	74.37 g-j	G138	81.43 b-k	85.31 a-j
G42	75.52 e-o	78.69 c-j	G144	87.15 a-d	84.77 a-j
G43-1	73.71 g-o	84.44 a-j	G146	80.58 b-l	87.12 a-i
G43-2	64.92 o-p	82.68 a-j	G147	79.13 c-m	89.07 a-h
G43-3	45.89 q	70.05 i-j	G148	79.41 b-m	92.01 a-f
G45-1	73.59 g-o	85.59 a-j	G152	80.32 b-l	100.00 a
G45-2	61.86 o-p	71.98 h-j	G154	72.55 h-p	88.87 a-h
G47	77.92 e-n	77.88 c-j	G161	90.84 a-b	87.01 a-i
G49	69.15 l-p	80.49 a-j	G173	80.05 b-l	88.00 a-h
G53	80.05 b-l	86.94 a-i	G177-1	80.28 b-l	84.59 a-j
G55	73.57 g-o	85.55 a-j	G179	74.40 g-o	82.86 a-j
			Karabey	90.84 a-c	94.42 a-d

P>0.01

Table 3. The ratio of root length per diameter class values (1 mm≤D≤ 2 mm) of eggplant genotypes infected with *F. oxysporum* f. sp. *melongenae* and non-infected (control) plants (%).

Genotype	Infected Plant	Control	Genotype	Infected Plant	Control
G1	6.68 p-t	10.42 a-f	G56	8.64 j-t	10.27 a-f
G2	11.13 d-r	16.09 a-b	G58	9.85 d-s	7.13 b-g
G4-1	7.19 o-t	4.41 e-g	G61	7.76 k-t	9.15 a-g
G4-2	13.60 a-k	10.85 a-f	G63	10.04 d-r	3.35 f-g
G5	8.94 h-t	5.93 c-g	G64	12.52 a-p	2.40 f-g
G7-1	14.33 a-j	14.44 a-c	G66	12.25 b-q	9.22 a-g
G7-2	7.51 k-t	8.27 a-g	G68	9.76 d-s	7.32 b-g
G8	8.64 i-t	10.30 a-f	G69	14.97 a-h	14.14 a-d
G11-2	13.21 a-o	13.55a-e	G73	9.94 d-r	5.81 c-g
G12	12.01 c-q	9.47 a-g	G80	12.19 b-q	13.61 a-e
G15	11.99 c-q	6.98 b-g	G88	18.43 a	12.96 a-e
G16	15.69 a-d	6.75 b-g	G 91	9.42 f-s	18.17 a-b
G20	12.79 a-o	7.44 b-g	G98	8.73 i-t	10.90 a-f
G21	9.33 f-s	8.34 a-g	G109	13.31 a-n	10.75 a-f
G22-1	14.06 a-j	8.83 a-g	G113	9.49 e-s	10.09 a-f
G22-2	7.46 l-t	4.87 d-g	G114	14.94 a-h	3.03 f-g
G23	15.59 a-e	13.49 a-e	G119	10.35 d-r	14.73 a-c
G33	14.89 a-h	11.19 a-f	G122	9.76 d-s	15.70 a-b
G35-1	7.40 m-t	9..15 a-g	G125	13.48 a-m	10.15 a-f
G36	13.53 a-l	9.00 a-g	G127	15.02 a-g	14.72 a-c
G39	8.94 g-t	10.87 a-f	G128	9.13 g-t	13.39 a-e
G40-1	4.57 e-g	11.54 a-f	G134	6.36 q-t	12.98 a-e
G40-2	3.13 t	11.76 a-f	G138	9.21 f-t	8.50 a-g
G42	17.66 a-c	14.43 a-c	G144	3.82 s-t	9.77 a-f
G43-1	12.57 a-p	13.33 a-e	G146	10.58 d-r	6.63 b-g
G43-2	14.73 a-i	10.95 a-f	G147	7.26 n-t	8.11 a-g
G43-3	8.68 i-t	15.78 a-b	G148	8.30 j-t	7.81 b-g
G45-1	14.03 a-j	8.25 a-g	G152	7.59 k-t	0.00 g
G45-2	15.31 a-f	17.54 a	G154	10.85 d-r	6.06 c-g
G47	12.82 a-o	10.27 a-f	G161	5.57 r-t	9.26 a-g
G49	11.24 d-r	12.43 a-f	G173	10.65 d-r	10.01 a-f
G53	7.89 k-t	7.58 b-g	G177-1	11.20 d-r	9.19 a-g
G55	10.29 d-r	6.98 b-g	G179	11.16 d-r	8.19 a-g
			Karabey	5.38 r-t	2.72 f-g

P>0.01

Table 4. The ratio of root length per diameter class values(D>2 mm) of eggplant genotypes infected with *F. oxysporum* f. sp. *melongenae* and non-infected (control) plants (%).

Genotype	Infected Plant	Control	Genotype	Infected Plant	Control
G1	6.16 i-l	4.11 b-j	G56	13.02 c-k	5.82 a-j
G2	11.76 c-l	13.88 a-c	G58	14.89 b-i	4.75 b-j
G4-1	14.25 b-i	2.60 d-j	G61	11.23 d-l	7.40 a-j
G4-2	8.77 g-l	10.60 a-h	G63	12.96 c-k	4.16 b-j
G5	10.74 d-l	1.84 e-f	G64	10.71 d-l	2.85 d-j
G7-1	19.39 b-e	5.52 b-j	G66	15.21 b-i	8.93 a-j
G7-2	21.13 b-c	8.86 a-j	G68	13.76 b-j	1.40 f-j
G8	10.91 d-l	4.85 b-j	G69	11.85 c-l	11.57 a-f
G11-2	13.05 c-k	11.10 a-g	G73	10.78 d-l	0.01 j
G12	11.79 c-l	1.68 e-j	G80	7.91 g-l	3.25 d-j
G15	15.05 b-i	6.92 a-j	G88	9.73 f-l	7.69 a-j
G16	12.78 c-l	5.41 b-j	G 91	13.95 b-i	6.63 a-j
G20	19.40 b-e	4.30 b-j	G98	9.17 g-l	0.00 j
G21	6.53 h-l	6.39 a-j	G109	11.44 d-l	4.93 b-j
G22-1	13.85 b-j	10.04 a-j	G113	10.31 e-l	12.52 a-d
G22-2	7.32 g-l	0.39 h-j	G114	14.01 b-i	0.00 j
G23	8.65 g-l	11.24 a-g	G119	19.20 b-f	0.90 g-j
G33	10.55 e-l	11.32 a-g	G122	8.41 g-l	7.38 a-j
G35-1	10.25 e-l	5.00 b-j	G125	11.15 d-l	11.62 a-f
G36	7.16 g-l	11.16 a-g	G127	12.69 c-l	16.20 a
G39	13.65 b-j	11.20 a-g	G128	6.91 h-l	7.72 a-j
G40-1	11.16 d-l	5.50 b-j	G134	7.39 g-l	11.37 a-f
G40-2	3.16 l	13.86 a-c	G138	9.34 g-l	6.18 a-j
G42	6.80 h-l	6.87 a-j	G144	6.09 i-l	5.45 b-j
G43-1	13.70 b-j	2.22 d-j	G146	8.82 g-l	6.24 a-j
G43-2	20.34 b-d	6.35 a-j	G147	13.60 b-j	2.80 d-j
G43-3	45.42 a	14.15 a-b	G148	12.28 c-l	0.17 i-j
G45-1	12.36 c-l	6.14 a-j	G152	12.08 c-l	0.00 j
G45-2	22.82 b	10.47 a-i	G154	16.58 b-g	5.05 b-j
G47	9.25 g-l	11.83 a-e	G161	3.57 k-l	3.71 c-j
G49	19.59 b-e	7.06 a-j	G173	9.28 g-l	1.97 e-j
G53	12.05 c-l	5.46 b-j	G177-1	8.51 g-l	6.20 a-j
G55	16.12 b-h	7.46 a-j	G179	14.43 b-i	8.94 a-j
			Karabey	4.23 j-l	2.84 d-j

P>0.01

Table 5. Average root diameter values (mm) of eggplant genotypes infected and non-infected (control) plants by *F. oxysporum* f. sp. *melongenae*.

Genotype	Infected Plant	Control	Genotype	Infected Plant	Control
G1	0.83 b-d	2.20 b-h	G56	1.47 a-d	1.70 c-h
G2	1.82 a-d	2.00 c-h	G58	1.54 a-d	1.82 c-h
G4-1	1.44 a-d	1.53 f-h	G61	1.48 a-d	1.46 g-h
G4-2	1.18 a-d	1.74 c-h	G63	1.45 a-d	4.34 a-b
G5	0.80 b-d	1.87 c-h	G64	1.35 a-d	2.10 b-h
G7-1	1.12 a-d	3.95 a-c	G66	1.67 a-d	1.98 c-h
G7-2	2.06 a-b	1.29 h	G68	1.29 a-d	2.25 b-h
G8	1.38 a-d	1.27 h	G69	1.80 a-d	1.57 e-h
G11-2	1.24 a-d	1.67 d-h	G73	1.48 a-d	2.99 b-h
G12	1.10 a-d	2.27 b-h	G80	0.98 a-d	3.19 b-h
G15	1.63 a-d	3.31 b-h	G88	1.29 a-d	2.32 b-h
G16	1.31 a-d	2.20 b-h	G 91	1.44 a-d	2.42 b-h
G20	1.22 a-d	2.54 b-h	G98	0.96 a-d	3.02 b-h
G21	1.09 a-d	1.50 f-h	G109	1.50 a-d	3.66 a-g
G22-1	1.80 a-d	1.60 d-h	G113	2.05 a-b	2.39 b-h
G22-2	0.89 b-d	2.04 c-h	G114	1.21 a-d	2.37 b-h
G23	1.26 a-d	1.44 g-h	G119	1.29 a-d	2.54 b-h
G33	1.31 a-d	2.11 b-h	G122	0.84 b-d	3.55 b-g
G35-1	1.86 a-c	2.21 b-h	G125	1.17 a-d	1.67 d-h
G36	1.08 a-d	1.49 f-h	G127	1.46 a-d	2.05 c-h
G39	1.58 a-d	1.54 f-h	G128	1.49 a-d	1.88 c-h
G40-1	1.87 a-c	2.87 b-h	G134	0.89 b-d	2.38 b-h
G40-2	1.79 a-d	2.19 b-h	G138	0.85 b-d	1.86 c-h
G42	0.76 c-d	2.00 c-h	G144	0.60 d	1.99 c-h
G43-1	1.50 a-d	3.10 b-h	G146	1.07 a-d	2.58 b-h
G43-2	1.31 a-d	2.27 b-h	G147	1.11 a-d	2.07 c-h
G43-3	1.85 a-d	2.55 b-h	G148	1.02 a-d	2.61 b-h
G45-1	1.24 a-d	3.82 a-d	G152	1.09 a-d	5.87 a
G45-2	1.39 a-d	2.93 b-h	G154	1.37 a-d	3.72 a-f
G47	1.07 a-d	1.88 c-h	G161	1.66 a-d	1.99 c-h
G49	1.27 a-d	4.06 a-e	G177-1	2.17 a	2.40 b-h
G53	1..64 a-d	1.62 d-h	G179	1.25 a-d	1.84 c-h
G55	1.82 a-d	2.50 b-h	G173	1.15 a-d	2.47 b-h
			Karabey	0.86 b-d	2.85 b-h

P>0.01

Table 6. Root surface area values (cm²) of eggplant genotypes infected and non-infected (control) plants by *F. oxysporum* f. sp. *melongenae*.

Genotype	Infected Plant	Control	Genotype	Infected Plant	Control
G1	38.36 f-g	367.72 b-h	G56	32.66 f-g	403.31 b-h
G2	389.89 a-c	164.23 h	G58	28.91 f-g	499.92 b-h
G4-1	25.39 f-g	556.88 b-h	G61	24.27 f-g	210.07 e-h
G4-2	25.62 f-g	548.21 b-h	G63	29.31 f-g	468.15 b-h
G5	5.50 g	351.50 b-h	G64	38.55 f.g	620.33 b-f
G7-1	6.17 g	237.41 d-h	G66	73.11 d-g	444.40 b-h
G7-2	21.92 f-g	233.48 d-h	G68	38.32 f-g	497.17 b-h
G8	24.96 f-g	239.69 c-h	G69	36.68 f-g	407.49 b-h
G11-2	28.24 f-g	188.26 g-h	G73	32.17 f-g	577.40 b-h
G12	20.82 f-g	447.62 b-h	G80	26.47 f-g	537.56 b-h
G15	28.66 f-g	322.29 b-h	G88	41.76 f-g	639.60 b-d
G16	27.99 f-g	410.81 b-h	G 91	457.53a	641.84 b-d
G20	10.99 g	379.93 b-h	G98	18.86 f-g	371.06 b-h
G21	37.97 f-g	431.34 b-h	G109	90.48 d-g	268.42 c-h
G22-1	31.63 f-g	399.52 b-h	G113	415.72 ab	455.18 b-h
G22-2	26.94 f-g	461.80 b-h	G114	58.54 f-g	630.25 b-e
G23	54.85 f-g	264.13 c-h	G119	6.71 g	207.21 e-h
G33	48.30 f-g	616.93 b-f	G122	5.24 g	235.47 d-h
G35-1	307.02 a-f	610.25 b-g	G125	70.75 e-g	475.96 b-h
G36	136.67 b-g	348.63 b-h	G127	99.85 c-g	421.69 b-h
G39	36.90 f-g	255.22 c-h	G128	367.50 a-d	446.91 b-h
G40-1	54.56 f-g	431.97 b-h	G134	21.21 f-g	275.20 c-h
G40-2	291.79 a-g	379.09 b-h	G138	17.56 f-g	390.83 b-h
G42	5.20 g	329.95 b-h	G144	11.08 g	228.11 d-h
G43-1	12.07 f-g	201.65 f-h	G146	34.16 f-g	743.79 a-b
G43-2	16.43 f-g	209.91 e-h	G147	23.52 f-g	461.58 b-h
G43-3	6.79 g	219.76 d-h	G148	24.25 f-g	572.43 b-h
G45-1	16.59 f-g	361.21 b-h	G152	24.15 f-g	1142.59 a
G45-2	13.70 f-g	196.45 f-h	G154	26.33 f-g	664.75 b-c
G47	82.94 d-g	354.78 b-h	G161	288.40 a-g	556.88 b-h
G49	11-31 g	212.83 c-h	G173	51.16 f-g	276.50 c-h
G53	39.14 f-g	253.57 c-h	G177-1	357.97 a-e	371.51 b-h
G55	33.70 f-g	501.61 b-h	G179	33.56 f-g	267.37 c-h
			Karabey	31.62 f-g	498.40 b-h

P>0.01

Table 7. Total root volume values (cm^3) of eggplant genotypes infected and non-infected (control) plants by *F. oxysporum* f. sp. *melongenae*.

Genotype	Infected Plant	Control	Root Change (%)	Genotype	Infected Plant	Control	Root Change (%)
G1	0.80 f-i	20.27 m-u	96.01 a-e	G56	1.21e-i	28.79 g-n	94.64 a-f
G2	1.94 e-i	8.14 u-v	75.29 k	G58	1.19 e-i	23.19 k-s	93.57 a-h
G4-1	0.91 f-i	44.04 c-f	97.92 a-e	G61	0.89 f-i	7.71 u-v	88.55 c-j
G4-2	0.80 f-i	24.78 j-r	96.85 a-e	G63	1.04 e-i	44.05 c-f	97.63 a-e
G5	0.11 i	26.97 i-q	99.58 a	G64	1.22 e-i	37.07 e-j	95.87 a-e
G7-1	0.17 i	23.57 k-s	99.23 a	G66	3.25 e-g	41.06 d-g	92.06 a-i
G7-2	1.12 e-i	7.50 v	84.78 g-k	G68	1.24 e-i	27.86 h-p	95.53 a-e
G8	0.89 f-i	7.41 v	88.36 d-j	G69	1.38 e-i	15.90 o-v	91.68 a-i
G11-2	0.93 f-i	7.86 u-v	88.22 e-j	G73	1.16 e-i	43.18 c-f	97.30 a-e
G12	0.61 g-i	24.05 k-s	97.56 a-e	G80	0.66 g-i	42.97 c-f	98.42 a-b
G15	1.16 e-i	59.79 a-b	98.05 a-d	G88	1.46 e-i	37.95 e-i	95.85 a-e
G16	0.91 f-i	42.57 c-f	97.84 a-e	G 91	14.27 d	24.17 k-s	41.29 l-m
G20	0.32 h-i	26.62 i-q	98.06 a-d	G98	0.45 h-i	28.04 h-o	98.37 a-b
G21	1.03 e-i	16.24 n-v	93.07 a-h	G109	3.48 e-f	24.83 j-r	85.52 f-j
G22-1	1.41 e-i	23.70 k-s	94.33 a-g	G113	21.45 b	41.21 d-g	47.94 l
G22-2	1.05 e-i	42.10 d-f	97.56 a-e	G114	0.17 i	37.38 e-j	95.08 a-f
G23	1.73 e-i	9.64 t-v	81.00 j-k	G119	0.22 i	13.39 r-v	98.31 a-b
G33	1.42 e-i	15.97 o-v	90.15 a-j	G122	0.12 i	21.28 l-t	99.25 a
G35-1	1.57 e-i	34.11 f-k	95.49 a-e	G125	2.08 e-i	19.67 m-v	89.31 b-j
G36	1.21 e-1	12.11 r-v	90.68 a-j	G127	3.66 e	23.19 k-s	84.13 h-k
G39	1.50 e-i	9.91 t-v	83.31 i-k	G128	26.22 a	40.93 d-g	34.80 m-n
G40-1	1.41 e-i	31.66 f-m	95.13 a-f	G134	0.59 g-i	16.37 n-v	96.34 a-e
G40-2	2.04 e-i	55.49 b-d	96.01 a-e	G138	0.38 h-i	15.17 p-v	97.48 a-e
G42	0.10 i	16.38 n-v	99.37 a	G144	0.17 i	10.35 t-v	98.52 a-b
G43-1	0.51 h-i	16.01 o-v	96.08 a-e	G146	0.92 f-i	40.32 e-h	97.12 a-e
G43-2	0.56 g-i	11.43 s-v	94.74 a-f	G147	0.66 g-i	23.98 k-s	97.24 a-e
G43-3	0.27 h-1	14.24 q-v	98.00 a-d	G148	0.67 g-i	37.06 e-j	98.16 a-c
G45-1	0.59 g-i	9.10 t-v	93.46 a-h	G152	0.66 g-i	66.71 a	98.78 a-b
G45-2	0.47 h-i	14.66 q-v	96.46 a-e	G154	0.87 f-i	47.41 b-e	98.08 a-c
G47	0.61 g-i	16.60 n-v	96.04 a-e	G161	2.94 e-h	34.08 f-k	90.88 a-i
G49	0.38 h-i	15.81 o-v	97.56 a-e	G173	1.16 e-i	14.43 q-v	26.59 n
G53	1.55 e-i	10.35 t-v	84.74 g-k	G177-1	17.12 c	23.30 k-s	91.154 a-i
G55	1.57 e-i	33.36 f-l	94.55 a-f	G179	1.06 e-i	14.32 q-v	92.69 a-i
				Karabey	1.71 e-i	55.14 a-c	96.88 a-e

P>0.01

Table 8. Root dry weight values (g) of eggplant genotypes infected and non-infected (control) plants by *F. oxysporum* f. sp. *melongenae*.

Genotype	Infected Plant	Control	Genotype	Infected Plant	Control
G1	0.06 d-h	0.68 c-k	G56	0.06 d-h	0.37 r-x
G2	0.03 d-h	0.35 s-x	G58	0.05 d-h	0.95 a-b
G4-1	0.07 d-h	0.24 u-y	G61	0.06 d-h	0.61 v-y
G4-2	0.05 d-h	0.76 c-g	G63	0.06 d-h	0.21 w-y
G5	0.09 c-d	0.35 s-x	G64	0.05 d-h	0.32 t-x
G7-1	0.03 d-h	0.51 k-s	G66	0.05 d-h	0.20 x-y
G7-2	0.06 d-h	0.21 w-y	G68	0.05 d-h	0.54 i-r
G8	0.05 d-h	0.23 u-y	G69	0.01 f-h	1.08 a
G11-2	0.04 d-h	0.40 o-u	G73	0.05 d-h	0.62 d-m
G12	0.05 d-h	0.61 d-m	G80	0.03 d-h	0.70 c-i
G15	0.03 d-h	0.58 g-n	G88	0.03 d-h	0.59 f-n
G16	0.04 d-h	0.45 m-t	G 91	0.33 b	0.29 t-x
G20	0.06 d-h	0.35 s-x	G98	0.05 d-h	0.96 a-b
G21	0.04 d-h	0.24 u-y	G109	0.14 c	0.82 b-c
G22-1	0.03 d-h	0.32 t-x	G113	0.39 b	0.69 c-j
G22-2	0.06 d-h	0.55 i-q	G114	0.06 d-h	0.68 c-l
G23	0.05 d-h	0.24 u-y	G119	0.01 g-h	0.74 c-h
G33	0.05 d-h	0.11 y	G122	0.04 d-h	0.44 m-t
G35-1	0.06 d-h	0.38 q-w	G125	0.07 d-f	0.32 t-x
G36	0.06 d-h	0.35 s-x	G127	0.08 c-e	0.44 m-t
G39	0.05 d-h	0.23 u-y	G128	0.35 b	0.61 d-n
G40-1	0.07 d-h	0.10 y	G134	0.04 d-h	0.77 c-f
G40-2	0.08 d-f	0.32 t-x	G138	0.04 d-h	0.57 h-p
G42	0.07 d-h	0.77 c-f	G144	0.01 h	0.74 c-h
G43-1	0.02 e-h	0.78 b-e	G146	0.03 d-h	0.50 l-s
G43-2	0.02 e-h	0.51 k-s	G147	0.05 d-h	0.31 t-x
G43-3	0.02 e-h	0.40 p-v	G148	0.08 d-e	0.52 j-s
G45-1	0.06 d-h	0.58 h-o	G152	0.07 d-g	0.35 s-x
G45-2	0.04 d-h	0.54 i-r	G154	0.03 d-h	0.46 m-t
G47	0.02 e-h	0.30 t-x	G161	0.08 d-e	0.80 b-c
G49	0.01 g-h	0.74 c-h	G177-1	0.79 a	0.79 b-d
G53	0.06 d-h	0.23 u-y	G179	0.05 d-h	0.61 e-n
G55	0.04 d-h	0.32 t-x	G173	0.06 d-h	0.30 t-x
			Karabey	0.07 d-h	0.53 i-r

P>0.01

Table 9. Root dry weight changes values (%) of eggplant genotypes infected and non-infected (control) plants by *F. oxysporum* f. sp. *melongenae.*

Genotype	Root dry weight changes (%)	Genotype	Root dry weight changes (%)
G1	89.51 a-g	G56	81.08 d-l
G2	89.47 a-g	G58	94.45 a-d
G4-1	71.00 l	G61	73.30 i-l
G4-2	92.54 a-d	G63	71.40 k-l
G5	73.33 i-l	G64	81.00 d-l
G7-1	92.54 a-d	G66	71.12 k-l
G7-2	71.51 k-l	G68	90.91 a-e
G8	76.60 f-l	G69	98.46 a
G11-2	88.20 a-h	G73	85.25 a-k
G12	91.77 a-d	G80	95.69 a-c
G15	93.94 a-d	G88	94.45 a-d
G16	91.11 a-e	G 91	13.27 o
G20	82.89 b-l	G98	94.79 a-d
G21	83.59 b-l	G109	82.13 c-l
G22-1	88.62 a-h	G113	43.83 m-n
G22-2	89.06 a-g	G114	90.19 a-f
G23	77.14 e-l	G119	98.20 a
G33	49.84 m	G122	90.23 a-f
G35-1	82.01 c-l	G125	75.88 g-l
G36	82.60 c-l	G127	81.25 d-l
G39	73.41 i-l	G128	41.43 m-n
G40-1	32.70 n	G134	94.37 a-d
G40-2	74.75 h-l	G138	92.33 a-d
G42	90.47 a-f	G144	98.62 a
G43-1	96.89 a-b	G146	92.43 a-d
G43-2	96.00 a-c	G147	82.07 c-l
G43-3	95.03 a-d	G148	83.95 b-l
G45-1	89.65 a-g	G152	76.90 e-l
G45-2	92.14 a-d	G154	91.61 a-d
G47	91.44 a-d	G161	89.46 a-g
G49	98.19 a	G177-1	69.94 l
G53	71.63 j-l	G179	2 .86 o
G55	85.81 a-j	G173	89.85 a-g
		Karabey	86.98 a-i
	P>0.01		

Table 10.Correlation relationship between root structures and disease severity of eggplant genotypes.

	Root length (cm)	Root surface area (cm^2)	Average diameter (mm)	Root volume	U< 0- 1mm	U: 1-2 mm	2 mm>U	Dry weight	Root dry weight % changes	Weight % variation
Disease severity	-0.49**	-0.49**	-0.20	-0.53**	-0.20	0.11	0.18	-0.38	0.38	0.25
Root length (cm)		0.97**	0.35	0.58**	0.35	-0.22	-0.30	0.49**	-0.54**	-0.42**
Root surface area (cm^2)			0.47**	0.59**	0.33	-0.25	-0.26	0.52**	-0.55**	-0.45**
Average root diameter (mm)				0.32	-0.35	0.05	0.39	0.29	-0.37	-0.33
Root volume(cm^3)					0.13	-0.05	-0.13	0.77**	-0.91**	-0.65**
U< 0-1						-0.59**	-0.88**	0.14	-0.10	-0.11
U: 1-2							0.12**	-0.06	0.01	0.03
2 mm>U								-0.14	0.11	0.11
Dry weight									-0.79**	-0.79**
Root dry weight % changes										0.72**

**P>0.01

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Released Varieties

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Registration of "Sezgin" Chickpea (*Cicer arietinum* L.) Variety

"Sezgin" is a chickpea (*Cicer arietinum* L.) variety developed and registered in 2019 by Eastern Mediterranean Agricultural Research Institute (EMARI) of Turkey. The variety is well adopted to winter conditions of Mediterranean, Aegean and South East Anatolia Region of Turkey. "Introduction Breeding Method" was used to develop the variety from ICARDA's FLIP0342C source material.

Plants of Sezgin variety are well adopted to mechanised harvest due to erect growth habit, 37-70 cm plant height and14-38 cm first pod height. Time to flowering is 63-114 days and time to physiological maturity is 107-178 days. Grain is beige colored and cornered which has 34-46 g 100-grain weight. Water absorption capacity is 0.38-0.41 ml/grain; water absorption index is 1.02-1.06%; swelling index is 2.28-2.38%; eight mm sieve value is 42.1-55.8%; Protein ratio is 23-24%. Time requirement for cooking is 55-59 minutes.

Sezgin variety yield potential is high however; high yield can be obtained if environmental conditions are favourable and good agronomic practices are applied; Average grain yield of field tests is 2.7 t/ha with tolerance to Ascochyta blight.

Figure 1. Plant growth habit, grain and pod morphology of the Sezgin variety (Original).

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Mart D, Öktem G, Can C and Özyiğit İ (2019). Ascochyta Blight (*Ascochyta rabiei*) Tolerance of Registered Chickpea (*Cicer arietinum* L.) Varieties at Southeastern Anatolia Region, World Conference on Sustainable Life Sciences (Wocols, Science for Life), 30th June-07th July 2019, Budapest, Hungary (Oral presentation)

Registration of "Caner" Chickpea (*Cicer arietinum* L.) Variety

"Caner" is a chickpea (*Cicer arietinum* L.) variety developed and registered in 2019 by Eastern Mediterranean Agricultural Research Institute (EMARI) of Turkey. The variety is well adopted to winter conditions of Mediterranean, Aegean and South East Anatolia Region of Turkey. "Selection Breeding Method" was used to develop the variety from single plant selected from ICARDA's segregating 05TH21C source material.

Plants of "Caner" variety are well adopted to mechanised harvest due to erect growth habit, 33-64 cm plant height and 9-29 cm first pod height. Time to flowering is 61-113days and time to physiological maturity is 103-180 days. Grain is beige colored and round-cornered which has 36-48 g 100-grain weight. Water absorption capacity is 0.44-0.46 ml/grain; Water absorption index is 1.05-1.10%; Swelling index is 2.36-2.37%; Eight mm sieve value is 53.8-56.0%; Protein ratio is 22-26%. Time requirement for cooking is 44-51 minutes.

Caner variety yield potential is high however; high yield can be obtained if environmental conditions are favourable and good agronomic practices are applied; Average grain yield of field tests is 2,7 t/ha with tolerance to Ascochyta blight.

Figure 1. Plant growth habit and grain and pod morphology of the Caner variety (Original).

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Registration of "Deren" Pea (*Pisum sativum* L.) Variety

"Deren" is a pea (*Pisum sativum* L.) variety developed and registered in 2020 by Eastern Mediterranean Agricultural Research Institute (EMARI) of Turkey. The variety is well adopted to winter conditions of Mediterranean, Aegean and South East Anatolia Region of Turkey. "Selection Breeding Method" was used to develop the variety from single plant selected from local population source materials.

Plants of "Deren" variety are well adopted to mechanised harvest due to 70-127 cm plant height and 12-37 cm first pod height. Time to flowering is 37-92 days and time to physiological maturity is 102-138 days. 100-grain weight is 14.0-18.6 g. Water absorption capacity is 0.25 ml/grain; water absorption index is 1.26-1.49%; swelling index is 2.41-2.73%; eight mm sieve value is 50.8-51.8%. Protein ratio is 26-27%. Time requirement for cooking is 50-54 minutes.

Average grain yield of "Deren" variety in field tests is 2.2 t/ha.

Figure 1. Plant growth habit and grain and pod morphology of the Deren variety (Original).

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Registration of "Akçalar" Hungarian Vetch (*Vicia pannonica* Crantz) Variety

Akçalar is a Hungarian vetch (*Vicia pannonica* Crantz.) variety developed by Transitional Zone Agricultural Research Institute and registered in 2019. Selection breeding method was used in breeding studies.

Morphological characteristics of the variety are as follows; ratio length/width of leaflet of second primary leaf in seedling is low, intensity of anthocyanin coloration on the base of the stem in seedling is weak, intensity of green color of foliage in plant is medium, time of beginning of flowering in plant is medium, hairiness of upper internodes in stem is strong, anthocyanin coloration of leaf axil in stem is medium, shape of tip of leaflet (on middle third of plant) in leaf is straight, width of leaflet in leaf is medium, anthocyanin coloration of nectaries in stipule is absent or weak, color of standard in flower is white, hairiness in pod is strong, length in pod (excluding beak) is medium, width of pod is medium, length of beak in pod is medium, number of ovules in pod is medium, seed weight is medium, seed shape is slightly irregular,

Ground color of testa in seed is greyish green, brown ornamentation in seed is speckles and blotches, extension of brown ornamentation in seed is large, blue-black ornamentation in seed is speckles and blotches, extension of blue-black ornamentation in seed is small, color of cotyledons in seed is orange.

Growth habit of Akçalar is erect and it grows to about 67-70 cm depending on the growing conditions. Akçalar is grown for herbage and seed. Green herbage yield, dry herbage yield, seed yield on average are 2740 kg da^{-1}, 690 kg da^{-1}, 140 kg da^{-1}, respectively. Quality characteristics of Akçalar as follows; thousand grain yield of it's seed is about 34.8 g, dry matter ratio is 91.83% (in herbage) and 92.08% (in seed), crude protein ratio is 18.92% (in herbage) and 28.0 1(%) (in seed), crude cellulose ratio is 26.22% (in herbage) and 6.5% (in seed), NDF (in herbage) is 44.21%, ADF (in herbage) is 33.06%, ADL (in herbage) 5.41%, RFV (relative feed value in herbage) is 132.9. Akçalar is resistant to pest and diseases. This Hungarian vetch variety is a winter crop for Central Anatolia and Transitional Zone and similar locations.

Figure 1. Flower and grain of the Akçalar variety (Original).

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Registration of "Karaman 2016" Dry Bean (*Phaseolus vulgaris* L.) Variety

"Karaman 2016" dry bean variety was developed by Transitional Zone Agricultural Research Institute and registered in 2016. One of the parents of Karaman 2016, 4F-675-1 coded line has a coarse-grained, climbing plant habits, but its tolerance to viral diseases is not good. In order to increase the line's tolerance to viral diseases and at the same time maintain the current grain size, hybridization was performed with the resistance source 4F-2833. From the obtained 4F-675-1 / 4F-2833 pedigree population single plants were selected using single plant selection method. In order to transfer the bacterial halo blight (*Pseudomonas syringae* pv. *phaseolicola*) disease resistance gene and earliness character to the 5th selected plant (4F-675-1/4F2833-5), it was hybridized with the foreign disease-tolerant Weihing variety in 2004. In 2009, single plant selection was made in the F_5 generation and in 2011 this material was taken for yield trials.

Karaman 2016 variety is semi-climbing (65-81 cm) and coarse grain type. Karaman 2016' grain is larger than the other climbing type varieties' grain. The number of days of flowering varies between 38-69 days and the number of physiological ripening days between 106-114 days.

Average yield in the registration trials was recorded 180.6 kg / da. In breeding trials, the highest yield obtained from Karaman 2016 is 350 kg da^{-1}. It is recommended for dry bean cultivating areas.

The variety, Karaman 2016 has a medium tolerance to bacterial diseases, and it attracted attention with its tolerance to root rot disease in the registration trials.

100 seed number, hydration capacity, swelling index, cooking time and protein rate of Karaman 2016 are between 35.2-42.0 g, 0.42-0.47 g/grain, 2.06-2.41%, 35-41 min. and 21.3-23.5%, respectively, and its cooking flavor is quite good. Breeder material and gradual seed production are conducted by TZARI.

Figure 1. Pod, plant and grain of the Karaman 2016 variety (Original).

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Registration of "Sabribey" Barley (*Hordeum vulgare* L.) Variety

Sabribey is two rowed barley (*Hordeum vulgare* L.) variety (Figure 1) developed by Transitional Zone Agricultural Research Institute (TZARI) and registered in 2019. Sabribey cross is CWB117-5-9-5/ ST5819//Kalaycı97 with YEA4193-0E-0E-0E-1E-0E pedigree. Crossing was made in 1998 and yield test began in 2004-2005 growing year.

Similar to cv. İnce04 and cv. Ünver, cv. Sabribey is two rowed cultivar and its spike is moderately long. Depending on the growing conditions, plan height varies between 85 and 100 cm. Since, Sabribey is medium early and has high adaptation ability, it can be grown all Medium Anatolian Region and Transitional Zone of Turkey. Thus, high yield can be obtained from both fertile and less fertile soils. Sabribey shows high tolerance to net blotch (*Pyrenophora teres*) and scald *Rhynchosporium commune* (formerly known as *R. secalis*) diseases.

When appropriate environmental conditions and good agronomic practices are provided, yield potential is high. The highest grain yields were 6254 and 6716 kg ha^{-1} in Eskişehir location during 2017-2018 growing years, respectively. Average yield of the variety was 4600 kg ha^{-1} in Eskişehir conditions. Suggested planting rate is between 400-450 seeds/m^2. Malting quality is good. Quality results of indicated that test weight 65.5 kg, thousand kernel weight 39.5 g, protein content 13.4%, sieve value 76.2%, hull content 9%, extract75.9, extract difference 7%, friability 28.0% .

Pre-Basic and Basic seeds of the Sabribey cultivar have been produced by TZARI. Certified seed of the Sabribey are produced by both private companies and state farms.

Figure1. Spike and grain of the Sabribey cultivar (Original).

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Registration of "NKU Asiya" Bread Wheat (*Triticum aestivum* L.) Variety

NKU Asiya is a winter bread wheat (*Triticum aestivum* L.) variety developed using combination breeding by Tekirdağ Namık Kemal University, Agricultural Faculty and registered in 2018. The pedigree of NKU Asiya is Selianka/Krasunia and its history TURCBWW05TD0065-099TD-099TD-099TD-015TD-0TD. Crossing was made in 2005 and grain yield test began in 2011-2012 growing year. The spike of the NKU Asiya variety is moderately long and density, white, awned. The flag leaf is twisted, dark-green, and with medium glaucousity. Grain is oval, semi hard andred color. NKU Asiya is a mid-tall variety, similar to Flamura 85 and Esperia varieties. Plant height is between 85 and 95 cm depending on the growing conditions. NKU Asiya variety is a winter type, mid-early, resistant to winter hardiness, good tolerant to drought, high ability of tillering and trashing, and since its wide adaptability, it can be grown safely not only in the Thrace-Marmara Region, but also in other wheat production areas of our country.

NKU Asiya variety is tolerant to powdery mildew *Blumeria graminis* f. sp. *tritici (*Syn. *Erysiphe graminis*) and to stripe rust (*Puccinia striiformis* f. sp. *tritici*) and moderate susceptible to leaf rust (*Puccinia triticina*). It shows high yield stability ranging from 6.3-8.4 t ha^{-1} in Thrace Region, however If environmental conditions are appropriate and agronomic applications are apply well, it has the ability to increase grain yield even more. The highest grain yield was determined in Tekirdağ location with mean value of 9.645 t ha^{-1} in 2012-2013 growing season. Suggested sowing rate is 500 seeds m^2. Depending on the soil type and structure and soil analysis results, it is recommended to apply 70 kg ha^{-1} pure phosphorus and 170-180 kg ha^{-1} pure nitrogen.

Bread-making quality is good. The mean values of some grain qualities of the official variety testing experiment (2016 and 2017) are; test weight 76.7 ±2.1 kg hl^{-1}, thousand kernel weight 35.4±3.0 g, protein content 13.3±1.3%, water absorption 56.1±1.7% and Zeleny sedimentation 50.1±11.1 ml, alveograph energy value (W) 202.4±16.5 10^{-4} joule. The highest quality values such as thousand grain weight, test weight, protein content, gluten ratio, gluten index, Zeleny sedimentation value, alveograph energy (W) and flour yield for the variety were analyzed with averages of 44 g, 79.1 kg/hl, 15.7%, 44.0%, 87.5, 68 ml, 230 joule and 71% respectively, in 2012-2013 growing season.

Pre-Basic and Basic seeds of the NKU Asiya variety have been produced by Tekirdağ Namık Kemal University, Agricultural Faculty. Certified seed of the NKU Asiya variety are produced by a private seed company.

Figure 1. Spike and grain of the NKU Asiya variety (Original).

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