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# Recent Developments in Triticale Breeding Research and Production - An Overview

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**ABSTRACT**

This paper reflects an overview and collates possibly new information about current triticale status in Poland and elsewhere. There will be considerable production, breeding research, biology, and agronomy of triticale. Considerable improvements were made in modern triticale cultivars with respect to agronomic performance, resistance to biotic and abiotic stresses and nutritional quality, in particular for human consumption and wider adoption as a viable commercial crop. In the past decades, new breeding tools and enabling technologies (doubled haploid, marker assisted selection, genomics selection, transgenic, functional genomics, and targeted genome editing) have been refined or developed anew and are successfully exploited in triticale improvement. Through, the integration of these tools and technologies with conventional plant breeding approaches, triticale biological potential has been enhanced to make this small grain species an economically successful crop.

***Keywords*:** Triticale, breeding, biotechnology, resistance, somaclonal, androgenic variation, grain production

## Triticale past

History of triticale dates back to XIX$^{th}$ century when hybrids between wheat and rye after spontaneous or intentional crossings were observed (Wilson 1876). Since then, almost over a century, triticale was considered as a scientific and/or breeding novelty. On the turn of XIX and XX centuries, many attempts were made to cross wheat and rye, but majority of them were ended with sterile triticale offspring. Such situation lasted until breeding techniques were elaborated and introduced to produce fertile hybrid plants called triticale. According to bibliographic data, in 1930's the name 'triticale' was coined combining *Triticum* and *Secale*, the Latin names of wheat and rye.

Crosses of durum wheat [*Triticum durum* (4x - AABB)] with rye [*Secale cereale* (2x - RR)] produced triploid embryo ABR $F_1$ (3x). After going through embryo rescue and chromosome doubling with colchicines (Pilch 2001) fertile hexaploid plants of primary triticale were obtained. For a better understanding, the simplified scheme is being shown in figure 1. Most often, the production of variety is much more complex. After a completion of crossing work, selection work is carried out in breeding plots to identify the high yielding genotypes.

It is known from numerous reports on triticale breeding research, that various types of primary triticale could be synthesized with different chromosomal constitutions after crossing different species of wheat with rye, e.g. crossings of *Triticum turgidum* (AABB) or *Triticum aestivum* (AABBDD) with rye produced either hexaploid (AABBRR) or octoploid (AABBDDRR) triticale, respectively. It is to indicate, that wheat is the mother plant and rye serves as the pollinator. It also has been tried to make the reversed crosses when rye served as mother plant and wheat as pollinator. The final product was called *Secalotricum*, but such attempts were unsuccessful so far. Secondary triticales

have been produced by crossing two differently composed primary triticales. The diversity of triticale lines can be enlarged by production of substitution triticales. In such a cross soft, hexaploid wheat with a genome AABBDD serves as mother plant, pollinator is secondary, hexaploid triticale with a genome AABBRR to give in a progeny substitution hexaploid triticale with a genome AABBRR or AABBRD.

It needs to be emphasized, that among various types of triticales, hexaploid triticale (durum × rye) has commercially been the most successful because of showing superior vigour and reproductive stability. The octoploid triticale type was produced by crossing common wheat × rye. Unfortunately, in comparison to hexaploid type the latter one suffers from greater genetic instability and associated floret sterility (Mergoum et al., 2009).

**Contribution of biotechnological methods into triticale breeding.**

The cross-incompatibility barrier between (4x) wheat and rye has limited the genetic base for triticale breeding. To overcome this problem, biotechnological methods like embryo culture technique, somatic embryogenesis, androgenesis (doubled haploid technology), molecular markers, and genetic engineering have been used in breeding of the crop. It is to underline that since very beginning, triticale has been difficult to obtain as *in vivo* crosses except through rescue of embryo culture. According to Zimny and Loerz (1996), the production of haploid triticale plants was described for the first time by Ya-Ying in 1973. So far, microspore and anther culture have been most widely used and incorporated into triticale breeding programs (Ahmed & Allam, 2003, Arseniuk and Walczewski 2014). These provided an opportunity to create haploid and doubled haploid plants within a single season, thereby reducing the time and cost of cultivar development. So far, 12 sustainable and highly productive triticale cultivars have been released on the basis of anther culture technology in Poland (Table 1).

Despite the fact, conventional triticale breeding focuses on the selection of superior progeny from segregating populations, and selection is mostly based on phenotypic characters. The breeders are looking for new approaches and tools to reduce the environmental effect on the selection of appropriate triticale genotype, since there is a confounding impact of environmental factors on phenotype. Breeding of new variety, takes up to 15-20 years and the release of an improved variety is not really guaranteed and it depends on the utilization of the best parental combination. So, this is the reason that the recent approaches in triticale and cereal breeding have been focusing on application of molecular marker techniques and DNA technology.

The application of molecular markers in triticale breeding research is quite extensive and its main uses include:

- Assessment of genetic diversity and characterization of germplasm collections (Niedziela et al., 2016; Kang et al., 2016.);
- Variety fingerprinting for identification, accelerating the development of individuals that combine favourable alleles, contributing to hybrid performance prediction, establishment the distinctiveness of new cultivars prior to registration and protection (Ma and Gustafson, 2006);
- Estimation of genetic distances between populations, inbreds and breeding material (Niedziela et al., 2016);
- Facilitation of the introgression of chromosomal segments from alien species and even tagging of specific genes (Hakeem et al., 2016);
- Detection of monogenic and qualitative trait loci (QTLs)(Reszka et al., 2007);
- Purity and stability of the seed and plant material (Góral et al., 2005);
- Identification of sequences of useful candidate genes, etc. (Hakeem et al., 2016).

**Response to biotic and abiotic stresses**

Triticale was developed with a hope that in addition to the high yield potential and good grain quality of wheat, it will combine the resistance/tolerance to the biotic and abiotic stresses of rye. Initially, diseases did not appear to reduce triticale yields greatly. This could be explained by limited triticale acreage worldwide. At early stages, the area of triticale was insufficient for pathogens to adapt to the crop to cause serious outbreaks of diseases. The importance of diseases started to increase, as the amount of land planted with the small grain species has been steadily expanded in majority of triticale producing countries. Among adverse factors, at the beginning, like stem rust, ergot, *Fusarium* head blight (FHB), and leaf spots were recognized (Arseniuk 1996). Other adverse factors that downgraded triticale grain quantity and quality for end users included its late maturity than wheat, preharvest sprouting and pedoclimatic conditions. All these adverse factors contributed to lower triticale feed classifications and have reduced economic returns. On the other hand, lack of crop insurance coverage in quite a number of countries, inadequate research investment, lack of production technology, perception about triticale end-uses, lack of good-quality pedigreed seed, limited marketing options for farmers resulted in increases of economic risks to produce triticale.

It is to indicate, that triticale is a crop on which pathogens of wheat and rye meet, but there is evidence that on triticale embedded more so called "wheat pathogens", than rye ones. For such a notable example many server races of *Puccinia recondita*, the causal agent of leaf rust. In the latter respect, triticale also appears to bridge direct contacts for a number of pathogens e.g. between physiological forms of the most important cereal rusts. Such contacts stimulate somatic hybridization on a triticale plant and may finally result in new pathogenicities and virulence factors. Such new emerged forms, are able to attack triticale, wheat and rye. In such cases, resistance genes are becoming ineffective. The first disease which occurred on this cereal in epidemic proportions was stem rust (*Pucinia graminis* f. sp. *tritici*) in Australia.

Leaf and stripe rusts caused, respectively by *P. recondita* f. sp. *tritici* and *P. striiformis*) also have gained importance everywhere in triticale grown areas, and especially in Poland. In recent years, at least in Poland, powdery mildew caused by *Blumeria graminis* occurred in epidemic proportions in quite a number of winter triticale cultivars. Similar phenomena have appeared with a number of other diseases caused by facultative pathogens, such as, the most damaging disease to triticale is the *Parasta gonospora* spp. leaf and glume blotch disease complex, *Zymoseptoria tritici* inciting speckled leaf blotch and other pathogens like *Cochliobolus sativus*, *Fusarium culmorum*, and *F. graminearum*, *Microdochium nivale*, *Bipolaris sorokiniana*, *Oculimacula yallundae* (Wallwork & Spooner) Crous & W. Gams) (synonym: *Pseudocercosporella herpotrichoides*), and *Gaeumannomyces graminis* var. *tritici* inciting head, leaf and seedling blights and foot, crown and root rots. In addition to fungal pathogens, triticale is affected by bacteria, viruses, virus-like organisms and nematodes (Arseniuk and Góral, 2015). Research reports have shown that triticale presents broad genetic diversity to abiotic stresses, like drought, frost and cold, pre-harvest sprouting, water logging, lodging, shattering, Al toxicities (Arseniuk and Walczewski 2014; Blum 2014; Arseniuk 2015). Triticale is also tolerant of low pH (acidic soils), grows well on sodic soils, and tolerates high in boron soils. Its high productivity and resilience to growing conditions become as important as wheat and it is so already in Poland.

**Cultivation and production**

Triticale was originally promoted as a new cereal crop that combines the superior agronomic performance and the end-use qualities of wheat with high resistance/tolerance to biotic and abiotic stresses and adaptability of rye to poorer pedo-climatic conditions. This small grain cereal species is also considered as germplasm resource of improvement genes for resistance to the above mentioned stresses in wheat. Unfortunately, so far, triticale has only been recognized to have potential as a fodder cereal and to some extent as promising cereal for energy supply because of its high biomass and grain yield. The harvested area varies from year to year, but this is steadily increasing. Over about 30 years, the progress in the total harvested area of triticale appeared quite rapid, e.g. in 1985, triticale globally was grown on 232,631 ha and in 2016, on 4,234,298 ha and in 2015, even on 4,559,828 ha. Thus, the growing area over 30 years increased 19,6 times (Figure 2).

On the other hand, in Poland in 1985 triticale was grown solely on 20,000 ha and in 2015 and 2016, cultivated on 1,516,168 ha and 1,373,529 ha, respectively, so over 30 years, the growing triticale area in Poland has been increased 75,8 times (Figure 3)

In 2016, top triticale grain producers were as follows: Poland produced 5,1 million metric tonnes (m. mt) on 1,4 million ha; Germany produced 2,4 m mt. on 396,1 thousands ha (th. ha), Belarus produced 1.6 m mt. on 0.5 m ha, France produced 1.4 m mt. on 334.2 th. ha, Russia produced 0.62 m mt. on 223 th ha and Hungary produced 0.5 m mt. on 139,1 th. ha (FAO Stat). Likewise, the grain tonnage, the growing area is also varying from year to year, but it also is steadily increasing. In 2016, worldwide, 15.2 million metric tons of triticale grain was produced on almost 4.2 million ha (Figure 4).

Figure 1. Illustration of primary triticale production by a single cross, Source: Adapted from https://search.credoreference.com/content/topic/triticale.embed

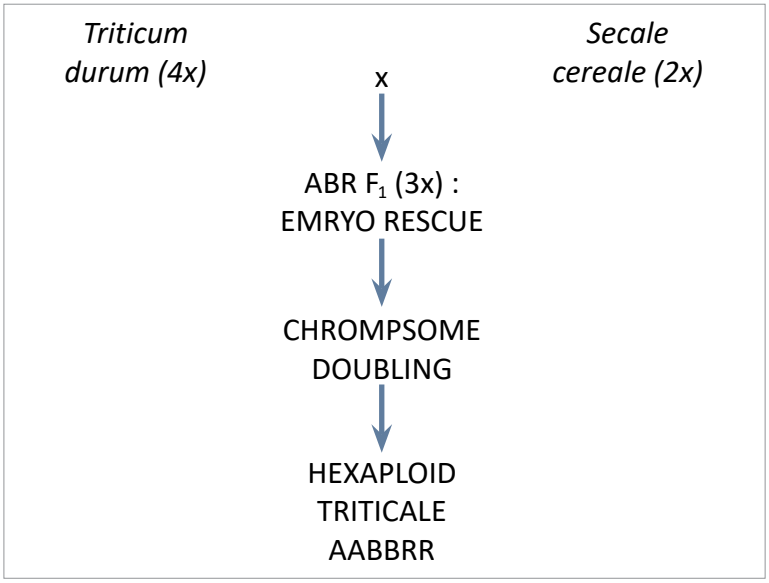



Table 1. Triticale cultivars developed by Polish breeders on basis of anther culture technology

| DANKO breeders | Standard and % of standard | STRZELCE breeders | Standard and % of standard | STRZELCE breeders | Standard and % of standard |
|---|---|---|---|---|---|
| **Winter triticale** | | | | Spring triticale | |
| Standard's yield | 81,1 dt/ha | Standard's yield | 81,1 dt/ha | Standard's yield | 87,7 dt/ha |
| Rotondo DH | 103% | Panteon DH | 105% | Dublet DH | 102% |
| Twingo DH | 94% | Borowik DH | 102% | Sopo DH | 105% |
| Torino DH | 103% | Probus DH | 112% | Mamut DH | 107% |
| **Winter wheat** | | Carmelo DH | 104% | Mazur DH | 105% |
| Standard's yield | 90,3 dt/ha | | | | |
| Izyda DH | 101% | | | | |

Figure 2. Triticale, area harvested in world over 1975 – 2016 (Source FAOStat)

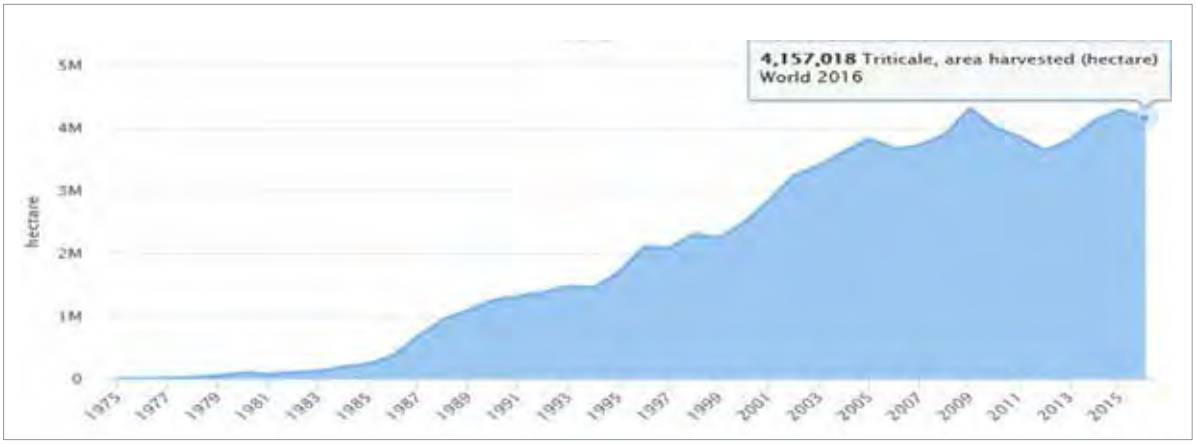
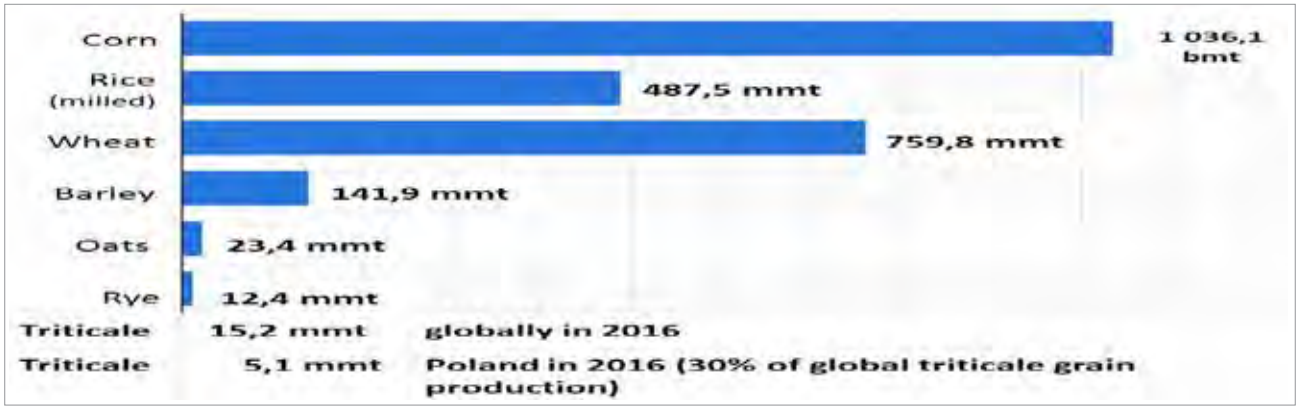


Figure 3. Triticale, area harvested in Poland in 1985 – 2016 (Source FAO Stat)


Figure 4. Global production of corn, rice and basic cereals, including triticale in Poland in 2016-2017 in billion (bmt) and million metric tonnes (mmt) (Source FAO Stat)



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# Determination of Yield, Quality and Winter Hardiness Characteristics of Some Triticale (x*Triticosecale* Wittmack) Genotypes in Pasinler and Erzincan Locations

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**ABSTRACT**

Triticale (x*Triticosecale* Wittmack) is a grain used in animal feed and is known for its high efficiency, high nutritional quality and resistance to stress factors. Triticale is an alternative plant used for the utilization of marginal areas due to these properties. This study was carried out at two different locations in Erzincan Merkez and Pasinler districts of Erzurum province. Two registered triticale varieties (Umranhanım and Tatlıcak 97) and 13 triticale lines in the advanced breeding stage were assessed comparatively in terms of efficiency, quality and cold resistance parameters. As a result of this study, genotypes 9, 10 and 12 were found suitable for the conditions of the region and considered to have a profitable production potential for producers. The Umranhanım cultivar is prominent in terms of its resistance to cold and its yield. In addition, it has been concluded that it is important to include cold test studies in breeding programs in regions where winter damage is experienced intensively as well as included in the selections

***Keywords*:** Triticale, yield, quality, winter hardiness

## Introduction

Genetically, Triticale (x*Triticosecale* Wittmack) is a cool climate cereal type obtained by hybridizing wheat and rye. Triticale obtained as a result of hybridization, aiming to combine the yield and quality of wheat with the high adaptability of rye, is grown in large areas in many countries around the world. Triticale can generate more yield than wheat, especially in barren regions where soil depth is not suitable for wheat cultivation and winters are severe. It is an important grain in human and animal nutrition due to high grain and green grass yield, rapid growth and development and high lysine content. In the evaluation of marginal areas, it is stated that triticale is the priority plant that is capable to increase the cultivation areas and production significantly with the development of new varieties (Müntzing 1989; Mergoum et al., 1992; Kun 1996).

Due to limitations in intensive agriculture and possible climatic changes, it will not be easy to increase the production to the extent that it will feed the growing world population. Therefore, the aim is to grow plant species which are more efficient in marginal soils. These plant species should be able to produce high yields with low inputs in marginal or low yield areas. Although, triticale is a newly cultivated plant species, it is rapidly spreading to various production systems (Pfeiffer 1994).

Soil conditions, such as drought, pH level, salinity, lack of trace elements and toxicity are factors limiting grain yield. Triticale is an advantageous plant in such conditions compared to commonly grown cereals. In fact, triticale has replaced rye and winter barley in saline soils in Belgium. In our country, it should be considered as an alternative crop in areas where winter barley cannot be cultivated due to

winter damage to reduce the feed gap. The results obtained from the studies have shown that triticale is an alternative crop to other cereals, especially wheat and barley (Benbelkacem 1998; Maças et al., 1998; Royo and Aragay 1998).

As a result of studies, it has been determined that triticale can give better benefit than other grains such as wheat, barley and oats (Gregory 1975). It is better adapted to sloping areas than wheat and barley and that it yields more than wheat in areas where soil depth is not suitable for wheat cultivation, the soil is barren and winters are severe (Martin and Maurer 1974; Rossi 1980; Yagbasanlar 1987). Since triticale is more efficient than other grain types in arid conditions, it is also important for regions where annual precipitation is limited and where irrigation is not possible (Salmon et al., 1996).

Considering the climate and geographic structure of the Eastern Anatolia Region, it is one of the most suitable regions for triticale farming. Therefore, it would be beneficial to develop and increase the production of new triticale varieties that can be offered to regional farmers. Today, triticale farming is mostly carried out to obtain animal feed (Dodge, 1989). Considering this aspect, triticale may be an alternative forage crop in areas which are important animal husbandry centers. (Farrel et al., 1983; Varughese et al., 1986; Belaid 1994; Pfeiffer 1994; Saade, 1995).

Due to the above mentioned characteristics, it is considered that triticale is an important alternative crop plant in Eastern Anatolia Region, especially in areas where wheat yield is low and unused barren land available for utilization. Therefore, it is important that triticale varieties which are suitable for the ecological conditions of the region and have high efficiency and yield stability are developed and offered to farmers. However, in addition to the genetic yield potential of a variety, the environmental conditions in which the plants are grown are also influence the yield. Under such circumstances, the stability of yield in various environmental conditions is of great importance. Therefore, it is necessary to determine that which genotypes have a stable yield under different environmental conditions. The aim of this study was to determine high efficiency, winter resistant and high quality genotypes that could be grown in Erzurum and similar ecological conditions.

## Materials and Methods

The trial was carried out for one year during 2017-18 in the trial areas in Erzurum, Pasinler district and Erzincan province under dry conditions. Umranhanım and Tatlıcak 97 types and 13 triticale lines were used in the study. The pedigrees and origin of the lines used in the trial are given in Table 1.

The winter season trial was established in two different locations in the "Chance Connected Full Blocks" trial design with three replications (Yildiz and Bircan 1991). Treatments were distributed to the parcels according to chance (Little and Hills 1978; Yildiz and Bircan 1991; Mead et al., 1994). Each parcel consisted of 6 plant rows of 6 m in length with 20 cm spacing, and the area of a parcel was 7.2 $m^2$ (6 m length x 1.2 m width).

Since there is no recommended date for planting triticale, the planting for the trial was carried out between the dates of September 1 and October 1 which is the most suitable date for planting winter wheat (Özcan and Acar 1990). The seeds were sown with row spacing 20cm apart at a depth of 4 - 6 cm and 475 seeds per $m^2$ with a seed drill. Ammonium nitrate (26%) was used as a nitrogen fertilizer source. Half of the nitrogen fertilizer was applied during sowing and the half during bolting at a rate of 6 kg N and 6 kg $P_2O_5$ per decare while the Phosphor fertilizer was all applied with the planting (Kıral and Özcan 1990; Akkaya 1993). Weed control was carried out during the tillering period in rainless and windless weather using the 2,4-D herbicide at a rate of 200 cc /da (Özcan 1994).

When the wheat reached at harvestable maturity, 50 cm was cut off from each parcel as edge effect and the remaining parts were harvested and blended with a parcel harvester. (Kıral and Özcan 1990; Akkaya 1993).

The observations were recorded on number of grains per Square Meter; maturation period, spikes in a row in the randomly selected one meter area within the harvest area of each plot were counted and these values were converted to the number of spikes per square meter.

**Grain Yield:** The grain product collected from each parcel was harvested and blended and weighed after cleaning with a small selector. The grain yields obtained as a result of weighing were collected and converted to kg / da.

**1000 Grain Weight**: Each piece of grain taken from the product was counted and weighed four times as 100 grains and the average was taken and multiplied with 10 to determine the 1000 grain weight (g).

**Hectoliter Weight**: A hectoliter measuring tool was used to weigh the grain product obtained from each parcel, weighed and calculated in kg.

**Protein in Grain**; Sample of wheat taken from each parcel was milled. As a result, obtained rate 100 g flouver was determined via NIR in %. Cold test studies were carried out according to the method used by Kucukozdemir (2016).

**Statistical Analysis**; The data were determined according to analysis of variance using SPSS 10.0 software package and when the medium was determined, Duncan's Multiple Range Test was used.

## Results and Discussion

In the study conducted with fifteen triticale genotypes, significant statistical differences were found among the characteristics of the examined genotypes in Erzincan location in parameters other than hectoliter weight and spike number per $m^2$. The mean values of all these properties and the statistical groups of the factors according to these averages ($P < 0.01$ and $P < 0.05$) are given in Table 2, 3, 4 and 5**.**

When investigated the location yields, overall means in the locations and Pasinler location were found significant according to $p<0.01$ and Erzincan location was calculated important according to $p<0.05$. In number of spikes per $m^2$, the locations and location averages were determined statistically significant according to $p<0.01$.

According to the location average Umranhanım variety (347 kg/da) had the highest grain yield, the values of genotype no. 10 (343 kg/da) and no. 12 (340 kg/ha) were very close to Umranhanım. Genotypes 1 (330 kg/da), 7 (307 kg/da), 9 (300 kg/da) and 8 (292 kg/da) were statistically in the same group with the maximum value. Genotypes 10 (553 kg/da), 12 (549 kg/da) and Umranhanım (540 kg/da) in Pasinler location were prominent with grain yield. In Erzincan, the highest grain yield was recorded in genotype no. 8 (184 kg/da) (Table 2). Kucukozdemir et al., (2016) carried out a study under Erzurum conditions for 10 years with 4 triticale and 3 wheat varieties to obtain the highest and stable grain yield of 418.9 kg/da with Umranhanım. Again, in a study on triticale in Erzurum's arid conditions, the total yield was between 219.9-466.6 kg /da and the differences between the Triticale genotypes were considered significant.

The highest number of spikes per $m^2$ in terms of location averages was found in genotype 4 (534) and genotypes other than Umranhanım, varieties 3, 8, 12 and 13 were determined to be statistically in the same group with maximum genotype. In Pasinler location, the highest number of spikes per $m^2$ was determined in genotypes 5 (675) and 4 (665), while the highest number of spikes per $m^2$ in Erzincan was determined in Tatlıcak 97 (435) variety. There were very significant differences between the genotypes in both locations (Table 2). The number of spikes per $m^2$ is one of the most important factors affecting yield and is highly influenced by environmental factors (Olgun et al., 1999). As a matter of fact, in a study on Triticale, the direct contribution of the spike number per $m^2$ on yield was calculated as 86.99% and the indirect contribution was calculated as 13.01% (Akgün et al., 1997). In a study carried out by Kucukozdemir (2002) in 5 locations, the lowest average number of spikes per $m^2$ was obtained in the Van location (202 units) and the highest in the Mus location (428.9 units). The reason for the significant differences in spike number per $m^2$ in this study is attributed to the climate factors of the locations and especially the difference in precipitation. In a study carried out by Akgün et al., (1997), they found that the number of spikes per $m^2$ among triticale varieties/lines ranged from 71.8 to 178.50 and the differences between genotypes were statistically insignificant. In another study in which summer cultivation was carried out in Erzurum's environmental conditions using 17 triticale genotypes and 1 bread wheat variety, it was manifested that the number of spikes per $m^2$ for the triticale genotypes and wheat ranged between 292.99 and 490.00, respectively (Tosun et al., 2000). In a trial carried out to compare Cumhuriyet 75 and Gediz 75 wheat varieties and triticale lines under Bornova conditions, the number of spikes per $m^2$ varied between 262.0-396.9, 269.4-396.9 and 312-390, respectively (Demir et al., 1981).

Both in terms of plant height and 1000 grain weight, according to the results of variance analysis, location averages and Erzincan location were found to be statistically significant ($P<0.01$) and Pasinler location was found significant ($P<0.05$).

The highest plant height according to location averages was found in Umranhanım (99.3 cm) and Tatlıcak 97 (99.3 cm) varieties and genotypes other than 5, 6 and 7 were statistically in the same group with maximum genotypes. In terms of plant height, Umranhanım (127 cm) was the tallest genotype in Pasinler location, while genotypes other than genotype 5 in this location were statistically in the same group as Umranhanım variety (Table 4). In the Erzincan location, genotype (75.7 cm) was found to be prominent while there were very significant differences between the genotypes. Demir et al., (1981) carried out a trial in triticale variety yield under Bornova conditions and determined that the most productive triticale lines in the experiment varied between 108.0-114.2 cm. Geren et al., (2012) studied some features regarding the grain yield and yield in general of different triticale varieties (Tacettinbey, Egeyıldızı, BDMT 06-5K, Karma, Tatlıcak 97, Mikham-2002, Focus, Melez-2001, Presto) under the environmental conditions of Menemen-İzmir during 2009-2011 and determined that there were significant differences in terms of plant height (87.7-119.2 cm).

In this study, the maximum value in terms of the

location averages for 1000 grains was obtained from genotype 5 (43.5 g) while genotype 12 (42 g), genotype 7 (42 g), Tatlıcak 97 variety (41), genotype 3 (41.5 g), genotype 6 (41.5 g), genotype 10 (41.5 g), genotype (41 g) and genotype 11 (40 g) were statistically in the same with the genotype with maximum value. The highest 1000-grain weight was obtained from genotypes 5 (45 g), 7 (44 g) and 6 (42 g) respectively in Pasinler location and all genotypes except Umranhanım and genotype 1 were statistically in the maximum group. In Erzincan, the highest1000-grain weight was measured in Tatlıcak 97 cultivars (44 gr) and no. 3 genotype (44 gr), and the differences between genotypes were statistically very significant (Table 2). Thousand grain weight is one of the important characteristics affecting grain yield in cereals (Tosun and Yurtman 1973; Gençtan and Sağlam 1987). Similarly, to this study, Tosun (1995) carried out a study by using 10 triticale species / lines in a greenhouse study reporting a 1000-grain weight of 32.3-45.49 (mean 39.03 g) and the differences between genotypes were considered to be very significant Tosun et al., (2000) carried out another study in Erzurum which reported a 1000-grain weight between 32.98 - 39.39 g and the differences between genotypes were determined to be significant. Likewise, a study carried out by Kumar et al., (1987) with six triticale varieties manifested a 1000 grain weight between 32.11-43.55 g as well as significant differences between the varieties.

When examined of Grain protein ratio, location averages and Erzincan location were detected statistically ($P<0.01$) significant and location averages were determined according to $P<0.05$. In Pasinler location was not found to be statistically significant. There were no statistically significant differences between the locations and Location average in terms of hectoliter weights.

While there was no statistical difference between the protein ratios of genotypes in Pasinler location, the highest protein ratio average among the locations was measured in genotype 2 (15.5%). According to the location averages, all genotypes except 3, 7, 8 and 13 were statistically in the same maximum group. In the Erzincan location, it was recorded that genotype 2 (17.1%) came to the forefront and statistically Umranhanım and Tatlıcak 97 were in the same group as the maximum group (Table 4). Similarly, to this study, Demir et al., (1981) in a study conducted under Bornova conditions, the highest yield triticale lines manifested a grain protein ratio varying between 10.66-13.05%. The chemical composition of triticale grain is similar to that of other grains, with a significant proportion (about 80%) of carbohydrates and about 95% of the carbohydrates is comprised of starch. Protein ratio is between 10% and 20%, fat ratio is between 2-4%. The percentage of carbohydrates decreases as wrinkles increase in seeds whereas protein and fat content increases. Therefore, as a result of breeding studies to reduce wrinkles, wrinkles have decreased, however the protein ratio has decreased. The amount of protein is related to the ratio of endosperm to pericarp and aleurone and the increase in grain size (increase in the amount of starch in the endosperm) can change this ratio. The recently obtained protein content of triticale is equivalent to wheat. However, the biological value of the protein in triticale is higher than in wheat (Skowmand et al., 1984; Dodge 1989) and has a balanced acid composition (Shealy and Simmonds 1973). In a study carried out in Erzurum with 14 triticale genotypes for 2 years, the hectoliter weights of the genotypes according to years were determined as 75.20-80.00 kg/hl, 73.20-79.60 kg/hl, respectively; 1000 grain weights were 25.50-33.50 g, 37.50-49.20 g, grain protein ratios were between 13.83-15.20%, 11.28-13.27%, respectively. It is reported that the precipitation especially in June and July 2016 increased the 1000 grain weights and yields however protein ratios decreased (Kucukozdemir et al., 2018).

According to the results of variance analysis, significant statistical differences were found in the vitality in coldness rates in this study ($P<0.01$). In the first test of the study at -17°C, the highest viability rate was found in genotype 2 (97%), followed by 10 (93%), 8 (90%) and Umranhanım variety (90%), respectively. Statistically, genotype 1 (87%), 11 (87%), 9 (83%), Tatlıcak 97 variety (83%), genotypes 5 and 13 (80%) were statistical in the same group with maximum genotypes in this test rating. Umranhanım varieties (70%) had the highest vitality ratio at -19°C while genotypes 10 (67%) and 2 (53%) were statistically ($P<0.05$) in the same group with Umranhanım variety. Statistically, Umranhanım variety (60%) and genotype 10 (50%) manifested significant vitality compared to the other genotypes at -21$^0$C de (Table 5). Triticale cultivation in winter and dry conditions exposes the plant to cold and drought in the winter. This is also the case in our other regions. The output of varieties that are resistant to winter and cold after winter is 80-95%, while the output of the fragile varieties is down by 40-50% (Kucukozdemir 2016).

## Conclusion

The yields, the number of spikes per square meter, hectoliter weight, protein content and performance in 3 different cold temperatures (-17, -19 and -21°C) of the candidate varieties have been compared with the varieties in the study. In terms of parameters

other than hectoliter weight, significant differences were determined between the genotypes. It has been determined that in terms of 1000 grain weight, yield, spike number per $m^2$, protein ratio, plant height and resistance to cold of genotypes 9, 10 and 12 are suitable for the regional conditions and have a profitable production potential for producers. Umranhanım varieties were found to stand out in terms of durability and yield. This is due to the maximum adaptation capability of the variety in the region where all varieties are developed. In addition, it is a very important that cold resistance observations are included in the breeding programs in regions such as East Anatolia with severe winters and high risk of frost to avoid producers in the region from being affected by winter damage and have a more efficient production.

Table 1. Genotypes used in the trial

| **Pedigrees of the genotytpes** | |
|---|---|
| Umranhanım | |
| Tatlıcak 97 | |
| Genotype no.1 | CIMMYT-1/MİKHAM-2002 |
| Genotype no.2 | FAHAD_5/MİKHAM-2002 |
| Genotype no.3 | ANOAS-3/GNU-14-1//KARMA |
| Genotype no.4 | POLLMER_2//GNU_7-2/NING7840/3/ZEBRA79/.../4/MİKHAM-2002 |
| Genotype no.5 | CT179.80/3/150.83//2*TESMO_1MUSX603/01-02KTVD-17 |
| Genotype no.6 | CT179.80/3/150.83//2*TESMO_1MUSX603/01-02KTVD-17 |
| Genotype no.7 | CT179.80/3/150.83//2*TESMO_1MUSX603/01-02KTVD-17 |
| Genotype no.8 | 6TB219/3/6TA876//6TB163/6TB164/4/2* ...../5/ANOAS-3/GNU-14-1 |
| Genotype no.9 | CT179.80/3/150.83//2*TESMO_1MUSX603/01-02KTVD-17 |
| Genotype no.10 | LAD 183/PORSAS_2 |
| Genotype no.11 | 05-06 TRİ-DİALLEL-14 |
| Genotype no.12 | 05-06 TRİ-DİALLEL-21 |
| Genotype no.13 | CT776.81//TESMO-1/MUSX 603/3/BAGAL_3/FARAS_1/3/ARDI_TOPO1419//ERIZO_9 |

Table 2. Grain yield and number of spikes per $m^2$

| | **Grain yield (kg/da)** | | | **Spikes per $m^2$ (Grain)** | | |
|---|---|---|---|---|---|---|
| Genotypes | Erzincan | Pasinler | Location average | Erzincan | Pasinler | Location average |
| Umranhanım | 153 a-d* | 540 a | 347 a | 389 ab | 381 cd | 385 cd |
| Tatlıcak 97 | 116 b-d | 501 ab | 308 a-c | 435 a | 511 a-c | 473 a-c |
| Genotype 1 | 146 a-d | 514 ab | 330 ab | 304 cd | 568 a-c | 436 a-d |
| Genotype 2 | 133 a-d | 398 c | 265 cd | 248 c | 415 b-d | 331 de |
| Genotype 3 | 122 a-d | 385 c | 253 cd | 349 a-c | 493 a-c | 421 a-d |
| Genotype 4 | 103 de | 373 c | 238 d | 403 ab | 665 a | 534 a |
| Genotype 5 | 139 a-d | 366 c | 253 cd | 328 a-c | 675 a | 501 a-c |
| Genotype 6 | 135 a-d | 429 bc | 282 b-d | 351 a-c | 513 a-c | 432 a-d |
| Genotype 7 | 173 ab | 440 bc | 307 a-c | 437 a | 600 ab | 519 ab |
| Genotype 8 | 184 a | 400 c | 292 a-d | 348 a-c | 460 a-c | 404 b-d |
| Genotype 9 | 165 a-c | 434 bc | 300 a-c | 297 cd | 549 a-c | 423 a-d |
| Genotype 10 | 133 a-d | 553 a | 343 a | 337 a-c | 611 ab | 474 a-c |
| Genotype 11 | 88 e | 194 d | 141 e | 333 a-c | 489 a-c | 411 a-d |
| Genotype 12 | 130 a-d | 549 a | 340 a | 311 cd | 376 cd | 343 de |
| Genotype 13 | 127 a-d | 136 d | 131 e | 285 cd | 229 d | 257 e |
| Total | 137* | 414** | 275** | 344** | 502** | 423** |

(*) According to the Duncan test, the averages shown with the same letter are not important in their group. ($p<0.05$)

Table 3. Plant height and 1000 grain weight

| | Plant height (cm) | | | 1000 grain weight (gr) | | |
|---|---|---|---|---|---|---|
| Genotypes | Erzincan | Pasinler | Location average | Erzincan | Pasinler | Location average |
| Umranhanım | 72 a-d* | 127 a | 99,3 a | 32 e | 34 b | 33 e |
| Tatlıcak 97 | 73,0 a-c | 126 ab | 99,3 a | 44 a | 39 ab | 41,5 ab |
| Genotype 1 | 62,3 c-e | 122 ab | 92,3 a-d | 42 ab | 34 b | 38 b-d |
| Genotype 2 | 69,0 a-e | 118 ab | 93,7 a-d | 30 e | 43 a | 36,5 de |
| Genotype 3 | 61,7 de | 118 ab | 89,8 b-d | 44 a | 39 ab | 41,5 ab |
| Genotype 4 | 66,7a-e | 119 ab | 92,8 a-d | 38 c-d | 38 ab | 38 b-d |
| Genotype 5 | 63,7 b-e | 111 b | 87,3 d | 42 ab | 45 a | 43,5 a |
| Genotype 6 | 64,0 b-e | 116 ab | 89,8 b-d | 41 a-c | 42 a | 41,5 ab |
| Genotype 7 | 63,3 b-e | 114 ab | 88,7 cd | 40 bc | 44 a | 42 ab |
| Genotype 8 | 70,0 a-e | 117 ab | 93,7 a-d | 36 d | 38 ab | 37 cd |
| Genotype 9 | 60,7 e | 126 ab | 93,2 a-d | 41 a-c | 41 ab | 41 a-c |
| Genotype 10 | 74,3 ab | 123 ab | 98,7 ab | 42 ab | 41 ab | 41,5 ab |
| Genotype 11 | 68,7 a-e | 121 ab | 94,7 a-d | 39 b-d | 41 ab | 40 a-d |
| Genotype 12 | 75,7 a | 121 ab | 98,2 ab | 42 ab | 42 a | 42 ab |
| Genotype 13 | 71,7 a-e | 123 ab | 97,5 a-c | 38 c-d | 39 ab | 38,5 b-d |
| Total | 67,8** | 120* | 93,9** | 39,4** | 40* | 39,7** |

(*) According to the Duncan test, the averages shown with the same letter are not important in their group ($p<0.05$)

Table 4. Grain protein ratio and plant height

| | Grain protein ratio (%) | | | Hectoliter weight (kg) | | |
|---|---|---|---|---|---|---|
| Genotypes | Erzincan | Pasinler | Location average | Erzincan | Pasinler | Location average |
| Umranhanım | 16,1 ab* | 12,5 | 14,3 ab | 75,2 | 78,8 | 77 |
| Tatlıcak 97 | 16,2 ab | 12,6 | 14,4 ab | 75,6 | 78,4 | 77 |
| Genotype 1 | 14,9 b-d | 12,6 | 13,7 ab | 74,8 | 78,8 | 76,8 |
| Genotype 2 | 17,1 a | 13,9 | 15,5 a | 74,4 | 77,2 | 75,8 |
| Genotype 3 | 13,8 de | 12,7 | 13,3 bc | 74,8 | 77,2 | 76 |
| Genotype 4 | 15,0 b-d | 13,2 | 14,1 ab | 75,2 | 78 | 76,6 |
| Genotype 5 | 14,3 c-e | 13,3 | 13,8 ab | 77,2 | 79,2 | 78,2 |
| Genotype 6 | 14,4 c-e | 12,9 | 13,7 ab | 77,2 | 78,8 | 78 |
| Genotype 7 | 13,7 de | 12,9 | 13,3 bc | 76,8 | 80 | 78,4 |
| Genotype 8 | 13,1 e | 12,6 | 12,8 bc | 71,6 | 75,2 | 73,4 |
| Genotype 9 | 14,3 c-e | 13,4 | 13,8 ab | 77,2 | 78,4 | 77,8 |
| Genotype 10 | 15,3 bc | 12,2 | 13,7 ab | 74,4 | 78,4 | 76,4 |
| Genotype 11 | 14,8 b-d | 13,3 | 14,0 ab | 76 | 75,2 | 75,6 |
| Genotype 12 | 15,5 bc | 12,3 | 13,9 ab | 72,8 | 78 | 75,4 |
| Genotype 13 | 14,5 cd | 9,0 | 11,8 c | 73,5 | 78 | 75,75 |
| Total | 14,9** | 12,6 ns | 13,7* | 75,1 ns | 78,0 ns | 76,5 ns |

(*) According to the Duncan test, the averages shown with the same letter are not important in their group ($p<0.05$)

Table 5. Vitality rates at different cold temperatures

| Genotypes | **-17°C (%)** | **-19°C (%)** | **-21°C (%)** |
|---|---|---|---|
| Umranhanım | 90 ab* | 70 a | 60 a |
| Tatlıcak 97 | 83 a-c | 47 c-e | 30 b |
| Genotype 1 | 87 a-c | 47 c-e | 3 ef |
| Genotype 2 | 97 a | 53 a-d | 17 b-e |
| Genotype 3 | 50 f | 20 f | 0 f |
| Genotype 4 | 70 c-e | 30 ef | 10 c-f |
| Genotype 5 | 80 a-d | 40 c-e | 20 b-d |
| Genotype 6 | 60 ef | 20 f | 0 f |
| Genotype 7 | 63 d-f | 50 b-d | 23 bc |
| Genotype 8 | 90 ab | 30 ef | 7 d-f |
| Genotype 9 | 83 a-c | 37 d-f | 17 b-e |
| Genotype 10 | 93 ab | 67 ab | 50 a |
| Genotype 11 | 87 a-c | 47 c-e | 10 c-f |
| Genotype 12 | 77 b-e | 57 a-c | 13 c-f |
| Genotype 13 | 80 a-d | 43 c-e | 20 b-d |
| Total | 79** | 44** | 19** |

(*) According to the Duncan test, the averages shown with the same letter are not important in their group ($p<0.05$)

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# The Effect of Heterosis on Yield Components of Opium (*Papaver somniferum* L.) Cultivars and Their Reciprocal Crosses

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**ABSTRACT**

Seven varieties of poppy (*Papaver somniferum* L.) registered in the National Cultivar List. By using their reciprocal crosses, heterosis on capsule yield, seed yield, morphine content and morphine yield was investigated. Experiments were conducted in the experimental fields of Opium Alkaloids Factory during the years 2009 and 2010. Heterosis effect of poppy varieties; capsule yield in terms of -56.76 to 95.81% , seed yield in terms of -57.40 to 89.29%, morphine content in terms of -13.21 to 15.70%, morphine yield in terms of -58.21 - 95.53% showed variation between. Higher heterosis ratios were observed in capsule-seed yields of the hybrids of parents TMO 3 and Kocatepe 96 and in morphine content yields of the hybrids of the parents Ofis 96, Afyonkalesi 95 and Kemerkaya 95.

***Keywords*:** Papaver somniferum L., heterosis, poppy, yield, yield components

## Introduction

There are 28 genus and about 250 species in the family Papaveraceae. *Papaver* species is considered to be very rich in our country. According to Davis (1988), out of total 39, 19 annual plants and 20 perennial plants (2 subspecies and 7 varieties). It is stated that 10 rounds of them, 2 sub-species and 4 varieties resides in *Papaver* species are endemic to Turkey. The family Papaveraceae, contains papaver alkaloids of secondary metabolites which are important within the genus (Ceylan 1994). *Papaver somniferum* L. (opium poppy) is a medicinally important genus and is one of the plants to be rich in alkaloids (Er 1997). Among those alkaloids, morphine, tebaine and papaverine are the most important ones (Baytop 1963). Poppies are also used in pharmaceutics in analgesic and antispasmodic drugs because of their pain relieving, local anesthetic and soporific characteristics (Baytop 1999; Gumuscu 2002). *Papaver* species usually shows the distribution of the northern hemisphere in temperate and subtropical regions. Poppy is cultivated in Turkey, India, Australia, France, Hungary, Check Republic and Chine under the inspection of United Nations (TMO 2004).

Among the poppy alkaloids, morphine has the widest range of use. Thus, several researchers conducted experiments to increase the morphine content of poppies. Several others, on the other hand investigated the effects of heterosis on morphine and seed yields together with various other yield contributing parameters of *Papaver somniferum* L. species. Researchers reported the existence of a certain heterosis with regard to morphine contents of parent combinations (Singh and Khanna 1991) and recommended the heterosis breeding for genetic improvement of poppy (Lal and Sharma 1991).

In the present study, current materials from the National Poppy Cultivar List were used to investigate the general and specific combining abilities, genetic variation among the cultivars, heterosis and heterobeltiosis effects and to develop materials with high morphine content and capsule-seed yield through the heterosis effects.

## Materials and Methods

Experiments were conducted over the experimental fields of Poppy Breeding and Seed Production Center in Bolvadin Town of Afyonkarahisar Province. The registered poppy cultivars of Suhut 94, TMO 3, Ofis 96, Kocatepe 96, Afyonkalesi 95, Kemerkaya 95, Afyon 95 from the National Cultivar List and reciprocal crosses were used as the plant material of the study (TTSMM 2013). According to long-term meteorological data for the period of January-December, experimental site has a monthly average temperature of 10.8 °C and monthly average precipitation of 31.5 mm. Experimental site has slightly alkaline unsaline loamy soils with high lime content, medium organic matter content, well available phosphorus levels and high potassium levels.

Cultivars were sown over 2 x 2 m plots in 4 rows on 09.10.2008 of the first year. Experiments were conducted in randomized block design with 3 replications. The experimental material is shown in Table 1. Crossbreeding and inbreeding processes were performed to get the relevant material for the yield experiments of the subsequent year and 42 (direct and reciprocal) hybrid lines were obtained by using each cultivar both as female and male. During the second year (2009-10), 49 hybrid lines together with ancestors, were sown over 3 x 2 m (6 $m^2$) plots in 5 rows on 22.10.2009 in partially balanced lattice experimental design. Diammonium phosphate was applied to each plot at a rate of 40 kg N /ha at the sowing time and 60 kg N /ha before the initial hoeing. Following the ripening of capsules, side rows were omitted to remove the side effect and the remaining plots were harvested on 15.07.2010.

In this study, heterosis effects only in economically significant traits were included. Heterosis was calculated by using the differences between parent and $F_1$ mean values taken from the variance analyses results [(% Heterosis = $F_1$ – PM / PM x100), where PM = ($1^{st}$ P + $2^{nd}$ P) / 2; PM: Mean value of two parents; P: Parent)] (Guler 1977; Kaymak 1980; Gumuscu 2002). Capsule samples were taken from the randomly selected 10 plants of which the other analyses have already been carried out. Then, morphine analyses were carried out at Laboratory of Opium Alkaloids Factory by using an HPLC (High Pressure Liquid Chromatography) device.

## Results and Discussion

Mean values for capsule yield, seed yield, morphine content and morphine yield of poppy parents and hybrids are provided in Table 2. Heterosis value for investigated traits of poppy hybrids are represented in Table 3.

Heterosis effects on capsule yield per hectare of poppy parents varied between -56.76 to 95.81% with the highest heterosis in line 27 (4x6) and the lowest heterosis in line 23 (4x1) (Table 3). While the capsule yield per hectare of the female plant with the highest heterosis combination was 1320.0 kg and the capsule yield per hectare of the male plant was 2021.0 kg, hybrid plant had a capsule yield per hectare of 3271.0 kg. Saini and Kaicker (1982) determined the heterosis value as 52.8% in capsule yield of poppy. Patidar (1994) carried out a study with 4 females, 31 males and 124 hybrids during 1988-99 and reported the heterosis values of parents for capsule yields as between 71.6 to 131.2%. Gumuscu (2002) reported the heterosis of some poppy lines and hybrids as between -33.92 to 45.30% for capsule yield.

Heterosis effects on seed yield per hectare of poppy parents varied between -57.40 to 89.29% with the highest heterosis in line 27 (4x6) and the lowest heterosis in line 3 (1x3) (Table 3). While the seed yield per hectare of the female plant with the highest heterosis combination was 1443.3 kg and the seed yield per hectare of the male plant was 2404.3 kg, hybrid plant had a seed yield per hectare of 3547.0 kg. Shukla et al., (2000) carried out heterosis for seed yield with 10 hybrids obtained from semi-diallel 5 different parents of poppy (*Papaver somniferum* L.) and indicated that higher variations in parents resulted in higher heterosis ratios in hybrids. Gumuscu (2002) determined the heterosis in seed yields of some poppy lines and hybrids as between -32.05 to 45.89%. Dodiya et al., (2005) carried out a study on heterosis and combining ability of poppy (*Papaver somniferum* L.) and evaluated the heterosis and combining ability with regard to seed yield. Shukla and Singh (2006) implemented a study about heterosis-related genetic incompatibility in poppy and evaluated 27 parents (24 male and 3 inseminator) and 72 hybrids of them with regard genetic incompatibility and heterosis in different characteristics and observed a heterosis of 86.58% in seed yield. Dubey et al., (2007) investigated combining ability and heterosis of poppy with regard to seed yield and other agronomic characteristics and observed a close relationship between latex yield and standard heterosis. Yadav et al., (2009) analyzed combining ability of $F_1$ and $F_2$ generations of 20 parents partially diallel poppy with regard to 5 quantitative

and 5 qualitative characteristics. Researchers indicated that high seed yields and morphine contents might be achieved by including high combining ability cultivars into multiple hybridization programs or by working with a population including entire possible hybrids of two-parent couplings.

Heterosis effects on morphine content of poppy parents varied between -13.21 to 15.70% with the highest heterosis in line 25 (4x3) and the lowest heterosis in line 35 (5x7) (Table 3). While the morphine content of the female plant with the highest heterosis combination was 0.63% and the morphine content of the male plant was 0.58%, hybrid plant had a morphine content of 0.70%. Sharma and Singh (1983) and Dubedout (1993) reported morphine contents of hybrids as between the values of parents. Popov et al., (1974) determined the morphine contents as between 0.45 to 0.60% for parents and between 0.7 to 0.9% for $F_1$ hybrids. Singh and Khanna (1975) indicated a heterosis in opium yield of poppy and did not observe a heterosis in morphine contents. Srivastava and Sharma (1987) carried out a three-year study on opium yield and morphine contents of parents and hybrids and observed respectively 32 to 66% and 25 to 39% higher values in hybrids than the parents. Singh and Khanna (1991) reported heterosis in morphine contents of parent combinations. Patidar (1994) determined better parent heterosis as 46.3% for opium yield and as 37.1% for morphine content. Sudhir and Shukla (1998) observed high heterosis ratios in morphine contents and low inbreeding depression for hybrids. Gumuscu (2002) reported the heterosis in morphine contents of some poppy lines and hybrids as between -24.21 to 44.62%. Shukla and Singh (2006) evaluated 27 parents and 72 hybrids and reported heterosis and genetic incompatibility in them with regard to different characteristics and observed heterosis 43.4% for opium yield and 11.74% for morphine content.

Heterosis effects on morphine yield of poppy parents varied between -58.21 to 95.53% with the highest heterosis in line 27 (4x6) and the lowest heterosis in line 23 (4x1) (Table 3). While the morphine yield of the female plant with the highest heterosis combination was 8,4 kg/ha and the morphine yield of the male plant was 9,5 kg/ha, hybrid plant had a morphine yield of 17,5 kg/ha. Khanna and Shukla (1988) observed a heterosis in triploids of $F_1$ generations in hybrids of *P. somniferum* L. and *P. setigerum*. Sharma et al., (1988) indicated high heterosis in raw opium yields of the materials. Patidar (1994) reported better parent heterosis as 46.3% for opium yield and 37.1% for morphine content. Lal and Sharma (1995) observed significant positive heterosis in opium yield and negative heterosis in alkaloid content. Gumuscu (2002) determined the heterosis in morphine yields of some poppy lines and hybrids as between 4.21 to 44.62%.

Since yield, earliness, plant height-like characteristics are generally affected by several genes and interactions, it has been impossible to develop homozygote dominant individuals even with long-term inbreeding studies. Hybridization most of the time allows to improve variability at the desired course and to get the varieties with new characteristic combinations (Aydemir 1982). Interactions among allele genes located in different locus of hybrid plants are thought to eliminate such limitations (Demlary 1977; Demir and Turgut 1999). It was also reported that $F_1$ tomato hydrides had better adaptations to adverse environmental conditions than the standard cultivars because of heterosis (Philouze 1976). Although, hybrid power is generally used in foreign-pollinating cultivars, it is also used in self-pollinating plants such as pepper, cucumber, poppy in which several seeds are obtained with the pollination of a single flower and hybrids are developed in this way (Eser et al., 2006). High number of seeds in capsules (5,000-20,000 seeds) makes the poppy available for hybrid seed production. Degree of kinship between parent lines is a significant issue in development of hybrid lines. Further, diverse the kinship, higher is the heterosis. Heterosis is most of the time not observed in kin-inbreed generations from the same origin (Demir and Turgut 1999). Therefore, in the present study, all the registered poppy cultivars in National Cultivar List were taken as the material and heterosis-induced genetic variations among the cultivars were investigated.

Variation analysis revealed the highest seed and capsule yields for hybrid 27 (4x6) and the highest morphine content for hybrid 44 (7x1). Heterosis and heterobeltiosis values in all of the investigated parameters of poppy hybrids were found to be significant. Higher heterosis ratios were observed in seed yields of the hybrids of parents 2 and 4 and in capsule yields of the hybrids of the parents 2, 3, 7 and 4. The hybrids with higher heterosis in their capsule and seed yields also had the higher general and specific combining abilities. With regard to morphine contents, higher heterosis ratios were observed in some hybrids of the parents 3, 5 and 6. Those hybrids had also higher general combining abilities.

At the end of this study, hybrid lines with high heterosis level in some traits and with high general-specific combining abilities were obtained. Heterosis level of the traits were different from each other since yield, morphine content, earliness and plant

height-like characteristics are controlled by several genes and the effects of each gene in heterosis are ambiguous. Therefore, heterosis may be at high level in one parameter and low in another. As indicated in an earlier study of Yadav et al., 2009, high seed yields and morphine contents might be achieved by including high combining ability cultivars into multiple hybridization programs or by working with a population including entire possible hybrids of two-parent couplings. Here in this study, new poppy lines were identified and data were provided to be used as the material of further studies. Poppy breeding studies are still on-going in the light of the current findings.

Table 1. Materials used in this research

| Variety number | Variety name | Seed color | Breeding method | Seed yield (kg/ha) | Capsule yield (kg/ha) | Morphine content (%) |
|---|---|---|---|---|---|---|
| 1st parent | Suhut 94 | Blue | Selective breeding | 1100-1400 | 1100-1300 | 0.60-0.70 |
| 2nd parent | TMO 3 | Pink | Hybridization | 810-1120 | 850-1320 | 0.85-0.90 |
| 3rd parent | Ofis 96 | Yellow | Selective breeding | 1130-1400 | 1000-1350 | 0.55-0.71 |
| 4th parent | Kocatepe 96 | White | Hybridization | 1100-1250 | 1200-1300 | 0.60-0.85 |
| 5th parent | Afyonkalesi95 | Yellow | Hybridization | 950-1200 | 900-1250 | 0.55-0.85 |
| 6th parent | Kemerkaya 95 | Yellow | Selective breeding | 900-1300 | 1000-1100 | 0.45-0.55 |
| 7th parent | Afyon 95 | Yellow | Selective breeding | 1140-1400 | 1170-1250 | 0.50-0.72 |

Table 2. Mean values for investigated traits of poppy parents and hybrids

| No | Hybrid | Capsule yield (kg/ha) | Seed yield (kg/ha) | Morphine content (%) | Morphine yield (kg/ha) | No | Hybrid | Capsule yield (kg/ha) | Seed yield (kg/ha) | Morphine content (%) | Morphine yield (kg/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 1st p. | 1611.3 | 1749.7 | 0.73 | 11.7 | **26** | 4x5 | 1475.9 | 1754.2 | 0.53 | 7.7 |
| **2** | 1x2 | 1274.3 | 1479,9 | 0.67 | 8.7 | **27** | 4x6 | 1670.5 | 1873.8 | 0.55 | 9.0 |
| **3** | 1x3 | 1686.7 | 2037.5 | 0.66 | 11.0 | **28** | 4x7 | 1321.5 | 1663.2 | 0.64 | 8.5 |
| **4** | 1x4 | 1465.7 | 1596.5 | 0.68 | 10.1 | **29** | 5th p. | 1631.7 | 2065.0 | 0.43 | 7.0 |
| **5** | 1x5 | 1621.5 | 1907.4 | 0.58 | 9.4 | **30** | 5x1 | 1621.5 | 1907.4 | 0.58 | 9.4 |
| **6** | 1x6 | 1816.2 | 2027.0 | 0.60 | 10.6 | **31** | 5x2 | 1284.5 | 1637.5 | 0.52 | 6.3 |
| **7** | 1x7 | 1467,2 | 1816.4 | 0.69 | 10.2 | **32** | 5x3 | 1696.9 | 2195.2 | 0.51 | 8.6 |
| **8** | 2nd p. | 937.3 | 1210.0 | 0.61 | 5.6 | **33** | 5x4 | 1826.4 | 2184.7 | 0.45 | 8.3 |
| **9** | 2x1 | 1274.3 | 1479.9 | 0.67 | 8.7 | **34** | 5x6 | 1477.4 | 1974.0 | 0.54 | 7.8 |
| **10** | 2x3 | 1349.7 | 1767.7 | 0.60 | 7.9 | **35** | 5x7 | 1475.9 | 1754.2 | 0.53 | 7.7 |
| **11** | 2x4 | 1128.7 | 1326.7 | 0.62 | 7.0 | **36** | 6th p. | 2021.0 | 2304.3 | 0.47 | 9.5 |
| **12** | 2x5 | 1284.5 | 1637.5 | 0.52 | 6.3 | **37** | 6x1 | 1816.2 | 2027.0 | 0.60 | 10.6 |
| **13** | 2x6 | 1479.2 | 1757.2 | 0.54 | 7.6 | **38** | 6x2 | 1479.2 | 1757.2 | 0.54 | 7.6 |
| **14** | 2x7 | 1130.2 | 1546.5 | 0.63 | 7.1 | **39** | 6x3 | 1891.5 | 2314.8 | 0.53 | 9.9 |
| **15** | 3rd p. | 1762.0 | 2325.3 | 0.58 | 10.2 | **40** | 6x4 | 1826.4 | 2184.7 | 0.45 | 8.3 |
| **16** | 3x1 | 1686.7 | 2037.5 | 0.66 | 11.0 | **41** | 6x5 | 1672.0 | 2093.7 | 0.56 | 9.1 |
| **17** | 3x2 | 1349.7 | 1767.7 | 0.60 | 7.9 | **42** | 6x7 | 1670.5 | 1873.8 | 0.55 | 9.0 |
| **18** | 3x4 | 1541.0 | 1884.3 | 0.61 | 9.3 | **43** | 7th p. | 1323.0 | 1883.0 | 0.65 | 8.6 |
| **19** | 3x5 | 1696.9 | 2195.2 | 0.51 | 8.6 | **44** | 7x1 | 1467.2 | 1816.4 | 0.69 | 10.2 |
| **20** | 3x6 | 1891.5 | 2314.8 | 0.53 | 9.9 | **45** | 7x2 | 1130.2 | 1546.5 | 0.63 | 7.1 |
| **21** | 3x7 | 1542.5 | 2104.2 | 0.62 | 9.4 | **46** | 7x3 | 1542.5 | 2104.2 | 0.62 | 9.4 |
| **22** | 4th p. | 1320.0 | 1443.3 | 0.63 | 8.4 | **47** | 7x4 | 1477.4 | 1974.0 | 0.54 | 7.8 |
| **23** | 4x1 | 1465.7 | 1596.5 | 0.68 | 10.1 | **48** | 7x5 | 1672.0 | 2093.7 | 0.56 | 9.1 |
| **24** | 4x2 | 1128.7 | 1326.7 | 0.62 | 7.0 | **49** | 7x6 | 1321.5 | 1663.2 | 0.64 | 8.5 |
| **25** | 4x3 | 1541.0 | 1884.3 | 0.61 | 9.3 | | | | | | |

Table 3. Heterosis (%) value for capsule and seed yield per hectare, morphine content and morphine yield

| *H*: Heterosis | | Capsule yield | Seed yield | Morphine content | Morphine yield | No | Hybrid | Capsule yield | Seed yield | Morphine content | Morphine yield |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **No** | **Hybrid** | ***H.*** | ***H.*** | ***H.*** | ***H.*** | **No** | **Hybrid** | ***H.*** | ***H.*** | ***H.*** | ***H.*** |
| **2** | 1x2 | -8.32 | -10.92 | 1.49 | -8.67 | **27** | 4x6 | 95.81 | 89.29 | -1.82 | 95.53 |
| **3** | 1x3 | -51.86 | -57.40 | -0.76 | -51.60 | **28** | 4x7 | 40.52 | 28.55 | 0.00 | -10.59 |
| **4** | 1x4 | -22.22 | 14.73 | 8.82 | -16.42 | **30** | 5x1 | -13.89 | -37.92 | -3.45 | -45.45 |
| **5** | 1x5 | -36.89 | -24.22 | -3.45 | -36.90 | **31** | 5x2 | -28.77 | -41.76 | 9.62 | -15.87 |
| **6** | 1x6 | -2.91 | 1.81 | 8.33 | 7.55 | **32** | 5x3 | -29.85 | -33.00 | 8.91 | -23.26 |
| **7** | 1x7 | -32.52 | -15.47 | -2.90 | -33.99 | **33** | 5x4 | -34.42 | 23.33 | 6.67 | 17.58 |
| **9** | 2x1 | 10.36 | 4.67 | 7.46 | 16.76 | **34** | 5x6 | 52.48 | 42.15 | 1.85 | 56.41 |
| **10** | 2x3 | -14.30 | -34.00 | 1.60 | -11.39 | **35** | 5x7 | -24.09 | -12.38 | -13.21 | -33.77 |
| **11** | 2x4 | 23.48 | 47.91 | 9.68 | 35.71 | **37** | 6x1 | -42.90 | -28.80 | 0.00 | -41.51 |
| **12** | 2x5 | 50.51 | 35.57 | 1.92 | 63.49 | **38** | 6x2 | -3.64 | -11.49 | 9.26 | 11.26 |
| **13** | 2x6 | -40.73 | -34.46 | 11.11 | -29.80 | **39** | 6x3 | -17.21 | -13.91 | 4.76 | -11.68 |
| **14** | 2x7 | -0.75 | -18.27 | -1.59 | -2.82 | **40** | 6x4 | -29.24 | -26.52 | 0.00 | -29.70 |
| **16** | 3x1 | -22.33 | -40.61 | -2.29 | -23.29 | **41** | 6x5 | -29.31 | -23.33 | 14.29 | -16.02 |
| **17** | 3x2 | -45.93 | -43.03 | 14.29 | -37.97 | **42** | 6x7 | -33.89 | -26.10 | 3.64 | -29.61 |
| **18** | 3x4 | -43.95 | -22.87 | 14.05 | -36.56 | **44** | 7x1 | -15.64 | -23.97 | 10.14 | -7.39 |
| **19** | 3x5 | -30.85 | -34.99 | 8.91 | -25.58 | **45** | 7x2 | 60.24 | 26.30 | -6.35 | 50.70 |
| **20** | 3x6 | -18.12 | -14.97 | 10.48 | -9.64 | **46** | 7x3 | -27.18 | -33.12 | -0.81 | -26.60 |
| **21** | 3x7 | 74.24 | 40.96 | -4.07 | 69.15 | **47** | 7x4 | 28.20 | 10.64 | 1.5 | 32.05 |
| **23** | 4x1 | -56.76 | -43.44 | -4.41 | -58.21 | **48** | 7x5 | -20.45 | -35.39 | -3.57 | -20.44 |
| **24** | 4x2 | 59.63 | 46.69 | 4.84 | 68,57 | **49** | 7x6 | -44.96 | -39.43 | 4.69 | -43.53 |
| **25** | 4x3 | -31.00 | -28.50 | 15.70 | -20.43 | | **Mean** | **-8.67** | **-9.57** | **3.58** | **-5.54** |
| **26** | 4x5 | -4.75 | -4.19 | 3.77 | 1.30 | | | | | | |

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# Performance of Wheat Genotypes for Grain Yield and its Attributes under Irrigation with Saline Water

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**ABSTRACT**

A field experiment was conducted in randomized block design in 3 replications at agriculture research farm, Jagan Nath University Bahadurgarh, Haryana, India with 7 wheat varieties currently grown in northern India to evaluate the impact of saline irrigation water on the grain yield and its attributes. The soil is clay loam with EC 118 µS/cm and water from nearby *Bidhro* canal having pH 7.6 to 8.4 depending upon rainfall. The observations were recorded on five randomly selected plants in each replication for each genotype and the mean data for grain yield and its attributes: plant height, number of tillers per plant, number of ears per plant, number of spikelet's per plant, dry weight of 100 grains, dry weight of grains per ear, test weight and grain yield per plant were subjected to analysis of variance. The result revealed significant difference among wheat genotypes for grain yield and its attributes. Wheat variety HD-2967 was found superior for grain yield (8.46), number of tillers per plant (6.10), number of ears per plant (5.55), dry weight of grains per ears (7.00) whereas WH-1080 scored highest for plant height (78.0) and dry weight of 100 seeds(4.35) and WH-1105 scored highest for test weight(1.31). These genotypes may possess genes for salinity tolerance as evidenced by their performance in predominantly saline soil and water used. They should be included in direct cultivation in such environment as well as hybridization programme to develop recombinants possessing high grain yield and tolerance to salinity.

***Keywords*****:** *Triticum aestivum*, grain yield, salinity

## Introduction

Wheat is one of the most important food crops of the world which contribute substantially in food and nutritional security. The maximum level of production and stability of yield are the two desired features in a commercial cultivar. Indeed, development of varieties showing wide adaptability has received increased attention in recent past (Preeti et al., 2016). However, production and productivity of wheat is affected by several abiotic constraints including high temperature, low temperature, drought and salinity. Salinity stress is among them the major abiotic stress affecting 7% of world land area (Flower et al., 1997). In India, an area of about 7 m.ha is already under salinity and 3.6 m.ha under sodicity problem and still larger area is coming under potential salinity problem due to injudicious use of water under canal irrigation system (Hollington, 1998). Salinity of growing media may harm the crop in different ways. It reduces uptake of water due to increased osmotic pressure of the soil water resulting from the increased concentration of salts. Salinity creates imbalance in uptake of essential mineral

elements. Accumulation of salts especially sodium ions in root zone may be toxic (Machado and Serrelheiro, 2017). Excessive salts act as an environmental stress and decrease plant growth potential. Salinity decreases the rate of seed germination, growth and development of plant, photosynthesis per unit leaf area and the utilization of photosynthates in growth of plant (Jose Ramon Acosta-Motos, et al., 2016).

Soils can be saline due to geo-historical processes or they can be manmade. The incoming water from the land brings salts that remain in soil because there is no outlet and the evaporation water does not contain salts. This is not only disturbs the plant water retention of the soil but also disturbs the cationic balance in root zone in most of the field crops (Machado and Serrelheiro, 2017).

A major proportion of ground water in the states of Gujarat (30%), Madhya Pradesh (25%), Punjab (41%), Uttar Pradesh (63%), Haryana (67%) and Rajasthan (84%) is brackish and good quality of water is occasional for assured irrigation (Kumar et al., 2017). Various scientific reports suggested that such water is unfit for irrigation as it contain badly salinity, sodicity or associated toxicity problems. When used for irrigation, brackish water would affect adversely the crop production. In absence of canal water or good quality water, most of the farmers use brackish water for irrigating their crops particularly in *Rabi* season. Wheat crop is semi-tolerant crop to salinity thus it is found that it might be grown with brakish water irrigation on the cost of some losses in yield. Different genotypes of wheat had varied limit to salt tolerance (Kumar et al., 2017). Therefore, it was considered necessary to test the newly evolved various wheat varieties against saline irrigation water for evaluating the effects on crop productivity and its physiological parameters. Jagan Nath University Bahadurgarh, Haryana is located by the side of *bidhro* drainage canal having drainage water from rainfall splash as well as excessive irrigation water which is having pH 7.69. As there is no other water available for irrigation therefore, we have compulsion to use such water for irrigation for wheat production at university campus. Under such situation it would be imperative to evaluate existing wheat variety grown in this region for tolerance to salinity and their relative yield potential.

## Materials and Methods

### Experiment location:

All the experiments were conducted in research farm of the Department of Agriculture, Jagan Nath University during *Rabi* season 2018-19. This location has latitude $28^0$62'80"N $76^0$75'34"E

**Soil:** The district Jhajjar, is a part of Eastern Haryana plain which forms a part of the Indo-Gangetic Plain. The soil at the location is clayey loam with Organic Carbon 0.69%, Total Nitrogen 0.16% and Available $P_2O_5$ (5.0 kg/ha).

**Irrigation Water:** This experimental field was irrigated with bidhro water. Water samples were collected from bidhro before sowing and were analyzed for various physiological parameters.

**Plant material and experimental design:** Seven wheat genotypes (WH-1105, WH-1124, HD-2967, DBW-88, WH-1142 WH-1080 WH-1025) obtained from CCS HAU Hisar were sown in a randomized block design with three replicates. Recommended doses of 120 kg N, 60 kg P, and 60 kg K/ha through Urea, Di-ammonium phosphate and Muriate of Potash, respectively were applied. Half of the N and full of P and K were applied at sowing while remaining half N was top dressed in two equal parts each at tillering and heading stages of crop. Fertilizer application preceed with irrigation with saline water from bidhro as flood irrigation. Plants were allowed to grow up to maturity. At physiological maturity flag leaves of the plants were collected for chemical analysis. Yield and yield components (plant height, number of tillers per plant, number of ears per plant, number of spikelet's per plant, dry weight of 100 grains, dry weight of grains per ear, test weight and grain yield per plant etc) were recorded after harvesting the plant at maturity.

**Statistical analysis:** The mean data for each trait was subjected to analysis of variance to ascertain significant difference among genotypes. Also the standard errors for mean difference for each trait were calculated. Based on statistical analysis superior genotypes were identified.

## Results

Analysis of variance revealed that significant difference among wheat genotypes for all the traits (data not given for brevity). It indicated that each genotype reacted differently to saline irrigation water. The comparison of means for each trait revealed that genotype WH-1080 recorded highest plant height (78.00) whiles the lowest being in DBW-88 (73.22). Highest number of tillers per plant was observed in HD-2967 (6.10) while lowest in DBW-88 (4.55). Maximum number of ears per plant was recorded for HD-2967 (5.55) while minimum in DBW-88 (4.33). DBW-88(16.66) recorded highest number of spikelet's per plant while WH-1025(10.66) recorded the lowest. Dry weight of 100 grains (g) was observed maximum in WH-1080(4.35) while minimum in WH-1142 (3.78). HD-2967(7.00) observed maximum for dry weight

of grains per ears (g) while WH-1025 for minimum (4.78). Highest test weight (g/cm$^3$) was observed in WH-1105(1.31) while lowest WH-1124(1.10).

The standard error or difference of mean for various trait was all most with acceptable range which revealed that the experiment was properly conducted and the sampling was effectively done.

Some genotypes figured superior for two or more characters. In this context genotype HD-2967 figured important for its superior performance number of tillers per plant, number of ears per plant and dry weight of grains pre ears (g) and grain yield. Coincidentally these are principle components of grain yield. It's seen that the genetic makeup of this genotype offers tolerance to salinity of irrigation water as well as soil. Also, WH-1080 exhibited superior performance for plant height and dry weight of 100 grains (g).

Salt tolerance in plant mainly determine by mechanisms including salt exclusion by root (Munns and Tester, 2008), deposition of salts in vacuoles, exclusion of salts from leaf margins and maintenance of turgor and osmotic potential under saline condition. On the other hand, the salt injuries are caused either by osmotic stress or ionic injury (Tang et al., 2015). In variably the performance of agronomic traits have been used to identify relative tolerance of wheat genotype to salt stress. A genotype performing better under salinity stress as well no stress condition is expected to posse's mechanism of homeostasis (Bartels and Sunkar 2005). Such genotypes are worthwhile it insures survival under salt stress and yield potential under optimal condition.

Involvement of this genotype in hybridization program may yield recombinants existing higher performance for grain yield as well as its component especially in the environment where soil salinity is predominant.

**Acknowledgement**

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Table 1. Various physiological parameters of water used for irrigation

| **pH** | **7.69** |
|---|---|
| TDS (ppm) | 1737.47 |
| EC (µS/cm) | 3393.43 |
| ORP (mV) | 202.08 |
| $F^-$ (ppm) | 1.25 |
| $Cl^-$ (ppm) | 1472.42 |
| $NO_3^-$ (ppm) | 22.98 |
| $SO_4^{2-}$ (ppm) | 329.39 |
| $PO_4^{3-}$ (ppm) | 0.16 |
| Total Hardness (ppm) | 1025.70 |
| Total Alkalinity (ppm) | 147.49 |

Table 2. Various agronomical parameters of wheat genotypes

| **Variety** | **Plant Height(cm)** | **No. of tillers per plant** | **No. of Ears per plant** | **No. of Spikelet per plant** | **Dry weight of 100 grains (g)** | **Dry weight of grains pre ears (g)** | **Test weight ($g/cm^3$)** | **Grain yield per plant** |
|---|---|---|---|---|---|---|---|---|
| **WH 1105** | 73.83±3.33 | 5.10±1.38 | 5.10±1.38 | 15.99±1.33 | 3.84±0.23 | 5.94±1.16 | 1.31±0.36 | 7.33±1.2 |
| **WH 1124** | 74.33±5.04 | 5.22±0.69 | 5.10±0.77 | 14.66±2.30 | 4.08±0.04 | 6.14±1.24 | 1.10±0.16 | 7.59±1.25 |
| **HD 2967** | 73.77±3.67 | 6.10±0.77 | 5.55±1.34 | 14.66±0.66 | 4.21±0.10 | 7.00±2.04 | 1.16±0.17 | 8.46±2.20 |
| **DBW88** | 73.22±5.82 | 4.55±0.69 | 4.33±1 | 16.66±1.15 | 4.07±0.17 | 5.98±0.66 | 1.23±0.17 | 7.48±0.75 |
| **WH 1142** | 73.35±4.03 | 5.33±0.67 | 4.99±0.88 | 15.22±1.57 | 3.78±0.47 | 5.44±0.94 | 1.16±0.29 | 6.11±1.06 |
| **WH 1080** | 78±3.52 | 5.21±1.89 | 5.10±1.95 | 11.99±0.66 | 4.35±0.18 | 5.05±1.42 | 1.20±0.24 | 7.39±0.86 |
| **WH 1025** | 77.77±6.84 | 5.77±0.83 | 5.33±0.57 | 10.66±0.66 | 4.27±0.09 | 4.78±0.56 | 1.18±0.20 | 6.29±0.57 |

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# Meteroglyph Analysis of Cowpea (*Vigna unguiculata* L.Walp) Elite Genotypes

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**ABSTRACT**

The present experiment was carried out at Director Farm, CCSHAU, Hisar during *kharif* 2017 to evaluate the performance of 30 selected elite genotypes of cowpea. The variably was studied both within and between groups. The genotypes, KBC 9 and DC 7-15 were placed in the medium fodder-medium grain yield producing group and could be utilized for both, fodder as well as grain production. Moreover, the genotypes (UPC 12-007, KBC-6, KBC-8 and GC 901) were included in high fodder- medium grain yield, which had good potential of grain production as well as excellent potential of fodder production. Likewise, the genotypes (PL-3 Sel., CPD 240 and RC 101) were included in medium fodder-high grain yield, which had good potential of grain production as well as excellent potential of fodder production. It could be utilized for dual purpose after extensive testing over time and space. None of the genotypes was placed in high fodder-high grain yield. So, there is an urgent need to breed for high fodder-high grain so that the maximum fodder as well as grain yield could be obtained simultaneously. Therefore, the hybridization among the diverse genotypes viz., UCP 12-007 (high fodder yield) with PL-3 Sel. (high grain yield) may be suggested for developing dual purpose genotypes through the transgressive segregation.

***Keywords*:** Cowpea, meteroglyph analysis, fodder yield, grain yield

## Introduction

Cowpea [*Vigna unguiculata* L.Walp] (2n=22) is a dicotyledonous crop in the order Fabaceae, subfamily Faboideae (Papillionoideae), tribe Phaseoleae, subtribe Phaseolinae, genus *Vigna*. The genus *Vigna* is pantropical and highly variable. In addition to cowpea, other members include mungbean (*V. radiata*), adzuki bean (*V. angularis*), blackgram (*V. mugo*), and the bambara groundnut (*V. subterranea*). Cowpea, *V. unguiculata* subspecies *unguiculata* includes four cultigroups: *unguiculata*, *biflora* (or *cylindrica*), *sesquipedalis*, and *textilis* (Ng and Maréchal, 1985). Moreover, *V. unguiculata* subspecies *dekindiana*, *stenophylla*, and *tenuis* are the immediate wild progenitors of cultivated cowpea. Based on the distribution of diverse wild cowpeas along the entire length of eastern Africa, east and southern Africa was proposed to be the primary region of diversity, and west and central Africa to be the secondary center of diversity (Singh et al., 1997; Timko and Singh, 2008; Lal and Vashisht, 2008; Rana, 2011). These authors also suggested Asia as a third center of diversity, specific for two cultigroups *cylindrical* (catjang bean) and *sesquipedalis* (yardlong bean).

Cowpea is one of the most important forage/pulse crops and generally grown in rainy as well as summer season. It can bear up drought as well as excessive rainfall up to some extent. Moreover, it responds well to irrigation and other management practices. Today, it is gaining importance due to its multi-purpose uses i.e. food, feed, vegetable, fodder and green manure. Its green tender plants and leaves are used for feeding

domestic animals as green fodder. Being a leguminous crop, it is also used for improving the soil fertility. It's green tender pods are used as vegetable and mature dry seed used as whole grain pulse for human consumption. It is a nutritive crop and rich source of protein both for animals as well as human beings (Sanjeev et al., 2015; Vu et al., 2016). It is well known fact that the genetic diversity is the primary requirement for a flourishing breeding plan. Collection and evaluation of genotypes is a pre-requisite for crop improvement, which provides a better scope for exploiting genetic diversity. The assessment of available diversity in germplasm gives essential and effective information to the crop breeder for further genetic improvement of yield (Nagalakshmi et al., 2010; Vu et al., 2016).

A lot of morphological diversity is available in cowpea which has the genetic base. For assessing the genetic divergence among the different genotypes, there are many important biometrical/statistical techniques viz. many, $D^2$ statistics, principal component analysis (PCA) and meterolygraph analysis, etc. Out of these techniques, meterolygraph analysis is found simple and semi-graphic method to assess the morphological variability present in a large number of germplasm lines/genotypes taken at a time. Anderson (1957) developed this technique to investigate the pattern of morphological variations among the genotypes in crop plants. Keeping above points in view, the present experiment was carried to study the morphological diversity available in cowpea for further utilization.

## Materials and Methods

For the present study, 30 diverse genotypes including check were selected from the material obtained for multi-location trials from the different research stations located in different parts of the country. The experiment was planned and carried out in RBD during *kharif* 2017, in Director Farm, CCS Haryana Agricultural University, Hisar (latitude 29°10′N, longitude 75°40′E and altitude 215.2m). The soil of Hisar is sandy loam. Each genotype was planted in paired rows, with 4 m row length, spaced 45 cm apart, with plant to plant distance of 15 cm. The sowing of genotypes was carried out by using dibbling method and all the recommended package of practices were adopted to raise the healthy and good crop stand. For data recording, five plants were randomly selected and tagged in each genotype. The observations were recorded on fodder yield/plant (g), grain yield/plant (g), number of branches/plant, number of pods/plant, number of seeds/plant and 1000-seed weight (g). The average value for the meteroglyph analysis was calculated as reported by Anderson (1957).

In meteroglyph representation, the X-axis depicts fodder yield/plant, while the Y-axis represents grain yield/plant. Each genotype is represented by a circle; the position of a circle on the graph is determined by the average fodder yield and grain yield/plant of the concerned genotype. The three rays emanating from each circle in left, middle and right side are presenting the three major grain yield contributing traits viz., number of pods/plant, number of seeds/plant and 1000-seed weight (g), respectively. The range of variation in trait is represented by the variation in length of the corresponding ray on all the circles. Therefore, the mean value of each trait was classified into three groups, viz., low (index score 1), medium (score 2) and high (score 3) (Kumar, 2015).

## Results and Discussion

The data of cowpea were analyzed and two traits viz., grain yield (kg/ha) and fodder yield (kg/ha) exhibiting the highest variability were identified. Singh et al., (2010) also reported genetic variability in cowpea.

In the present study, grain yield (kg/ha) and fodder yield (kg/ha) were plotted on the X and Y-axis, respectively. For each genotype, the mean values of X and Y were used to determine its position in graph which is marked by a small circle. Thus, each genotype is represented by small circle on the graph (Fig.1). The other characters for different genotypes were represented as rays on the respective circles. The ray of all the three characters emanating from a definite position on circle i.e. number of pods/plant, number of seeds/pod and 1000-seed weight (g) on left, middle and right of the circle, respectively. The range of variation in these traits is represented by the variation in the lengths of the corresponding ray on all the circles. Therefore, the mean values of each trait were classified into these groups viz., low (index score 1), medium (index score 2) and high (index score 3). All the cowpea genotypes for number of pods/plant were classified into three groups i.e. low (30), medium (30-40) and high (>40). Likewise, for number of seeds/pod the genotypes were also classified as low (< 9), medium (9-11) and high (>11). Similarly, for 1000-seed weight (g) the genotypes were grouped as low (<9g), medium (9-11g) and high (>11g). As a result, the length of each ray on a circle is short (low mean value), medium (medium mean value) or long (high mean). A circle along with rays emanating from it is called a glyph (Fig. 2).

The X and Y-axis of the graph are also demarcated into low, medium and high mean values as shown in Fig 1. This divides the entire graph into nine quadrangles, each quadrangle representing one

variability group. In cowpea, variability was also studied by various workers (Nagalakshmi et al., 2010; Singh et al., 2010; Kumar et al., 2015; Sanjeev et al., 2015). The sufficient variations were founded within a group as well as among the groups.

In general, the worth of an individual genotype was assessed from the sum of index scores for all the traits represented in the graph. Highest total index score (76) was obtained for 1000 seed weight. The genotype, PL-3 Sel. of cluster III had the highest total index score (13) which grouped into high score for seed yield/plant, number of pods/plant, number of seeds/pod and high score for number of seeds/plant. In cluster I, genotype DCS 47-1 had the lowest total index score (6) which distributed into low score for score for seed yield/plant, number of pods/plant, number of seeds/pod, dry fodder yield/plant and medium score for 1000-seed weight/plant.

In cluster IV genotypes GC 1110, KCB 9 and DC 7-15 grouped into medium score for seed yield per plant as well as for dry fodder yield per plant. In cluster III, PL-3 Sel., PGCP 28, TC 161 and CPD 29 showed high score for seed yield per plant and low score for dry fodder yield per plant. In cluster II, the highest number of genotypes (10) was observed which were distributed into medium dry matter yield per plant with low number of tillers per plant. Cluster I observed the lowest number of genotypes (2) which was distributed into low dry fodder yield/plant with low seed yield/plant (Table 3).

The genotypes, KBC 9 and DC 7-15 were placed in the medium fodder-medium grain yield producing group. These genotypes could be utilized for both, fodder as well as grain production. Moreover, the genotypes (UPC 12-007, KBC-6, KBC-8 and GC 901) were included in high fodder- medium grain yield, which had good potential of grain production as well as excellent potential of fodder production. It could be utilized for dual purpose after extensive testing over time and space. Likewise, the genotypes (PL-3 Sel., PCP-07-272, CPD 240 and RC 101) were included in medium fodder-high grain yield, which had good potential of grain production as well as excellent potential of fodder production. It could be utilized for dual purpose after extensive testing over time and space.

None of the genotypes was placed in high fodder-high grain yield. This may be due to low photosynthetic/physiological efficiency of cowpea genotypes as well as improper translocation and petitioning of photosynthetic components (Vu et al., 2017). So, there is an urgent need to breed for high fodder-high grain so that the maximum fodder as well as grain yield could be obtained simultaneously. Therefore, the hybridization among the diverse genotypes viz., UCP 12-007 (high fodder yield) with PL-3 Sel. (high grain yield) may be suggested for developing dual purpose genotypes through the transgressive segregation.

This finding indicated the non-linear relationship of seed yield/plant with dry fodder yield, however, it exhibited positive linear relationship with other contributing traits. Keeping the importance of seed yield contributing traits in consideration, these genotypes may be used in further yield improvement. These results support our contention that groupings made on the basis of metroglyph of diagnostic features contribute towards preliminary identification of diversity grouping of breeding entries which have undergone random mating for several generations and also for their worth in the breeding programme.

## Conclusions

It was concluded from the present study that the cowpea genotype, UCP 12-007 was high in the fodder and PL-3 Sel. was the highest in seed yield production and could be used for commercial cultivation after testing over time and space. Moreover, genotype (CPD 240) was included in medium fodder-high seed yield, which had excellent potential of seed production as well as good potential of dry fodder production. It could be utilized for dual purpose after extensive testing over time and space.

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Table 1. List of genotypes utilized during experiment

| Sr. No. | Genotype | Sources | Sr. No. | Genotype | Sources |
|---|---|---|---|---|---|
| **1.** | PL-3 Sel. | Pant Nagar | 16. | KBC-8 | UAS, Bangalore |
| **2.** | GC 1203 | Gujarat | 17. | Goa Cowpea-3 | Goa |
| **3.** | PGCP 28 | Pant Nagar | 18. | Pant Lobia-3 | Pant Nagar |
| **4.** | TC 161 | Tamil Nadu | 19. | DCS 47-1 | Dharward |
| **5.** | RC 101 | Rajastan | 20. | KBC-6 | UAS, Bangalore |
| **6.** | CPD 240 | NAU, Navsari | 21. | GC 1207 | Gujarat |
| **7.** | KBC 10 | UAS, Bangalore | 22. | TPTC-29 | Andha Pradesh |
| **8.** | CPD 29 | NAU, Navsari | 23. | PCP-07-272 | Rahori |
| **9.** | UCP 12-007 | Uttar Pradesh | 24. | TC 150 | Tamil Nadu |
| **10.** | GC 1304 | Gujarat | 25. | KBC 9 | UAS, Bangalore |
| **11.** | VCP 09-019 | - | 26. | PGCP-54 | Pant Nagar |
| **12.** | DC 7-15 | Dharward | 27. | GC 901 | Gujarat |
| **13.** | Chirodi | - | 28. | PGCP-23 | Pant Nagar |
| **14.** | CS 88 | HAU, Hisar | 29. | GC1110 | Gujarat |
| **15.** | PTB-1 | Pattampi | 30. | GC-3 | Gujarat |

Source: Department of Agricultural Meteorology, CCS Haryana Agriculture University, Hisar.

Figure 1. Agro-meteorological data recorded during the period of experimentation from May to October, 2017. (Source: Department of Agricultural Meteorology, CCS Haryana Agriculture University, Hisar.)

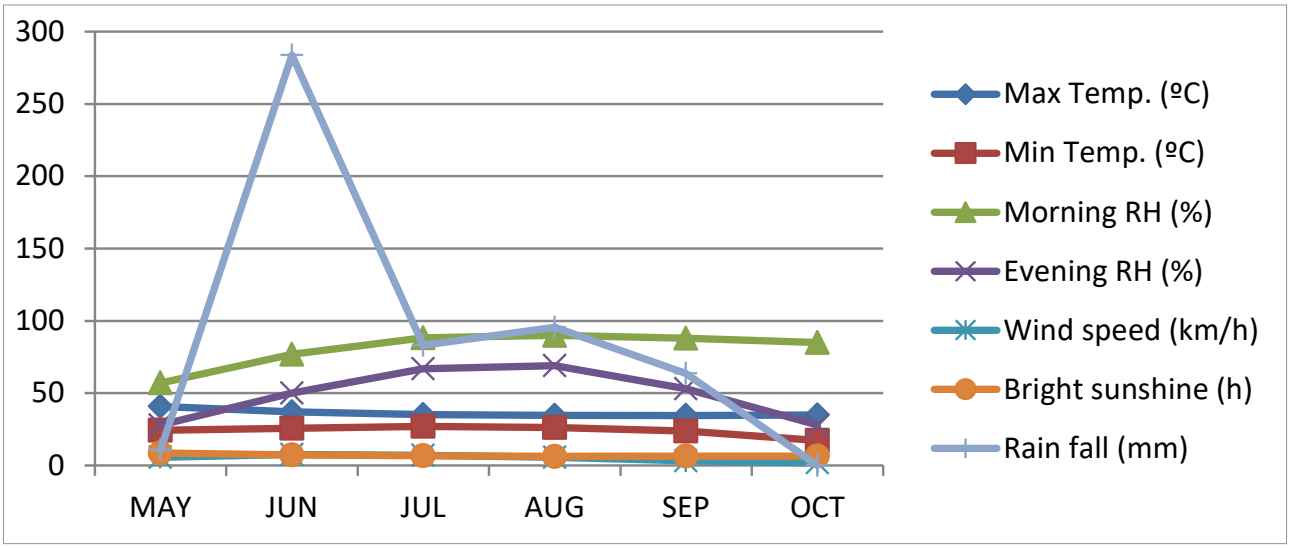

Figure 2. Meteroglyph analysis in cowpea. Grain yield (kg/ha) is used as the X-axis, while the other trait fodder yield (kg/ha) is plotted on the Y-axis. For each genotype, the mean values of X and Y were used to determine its position, which is marked by a small circle. Thus, each genotype is represented by small circle on the graph

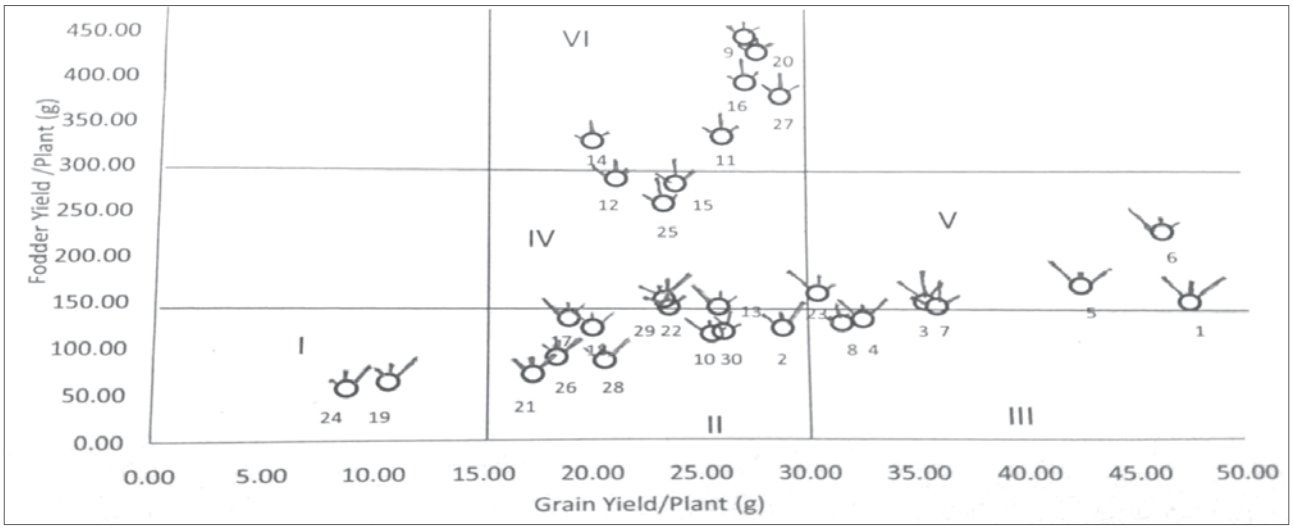


Table 2. Distribution of thirty accessions of cowpea into different clusters

| Cluster | Number of accessions | Composition of cluster | Distribution |
|---|---|---|---|
| **I** | 2 | DCS 47-1, TC 150 | Low dry fodder yield/plant with low seed yield/plant |
| **II** | 10 | GC 1203, GC 1304, Chirodi, Goa Cowpea-3, Pant Lobia-3, GC 1207, TPTC-29, PGCP-54, PGCP-23, GC-3 | Low dry fodder yield/plant with medium seed yield/plant |
| **III** | 3 | TC 161, CPD 29, KBC 10 | Low dry fodder yield/plant with high seed yield/plant |
| **IV** | 4 | DC 7-15, PTB-1, KBC 9, GC1110 | Medium dry fodder yield/plant with medium seed yield/plant |
| **V** | 5 | PL-3 Sel., RC 101, PGCP 28, CPD 240 | Medium dry fodder yield/plant with high seed yield/plant |
| **VI** | 6 | UCP 12-007, VCP 09-019, CS 88, KBC-8, KBC-6, GC 901 | High dry fodder yield/plant with medium seed yield/plant |

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# Genetic Studies on *Triticum timopheevi* Based Cytoplasmic Genetic Male Sterility (CGMS) System in Relation to Hybrid Seed Production in Wheat (*T. aestivum* L.).

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**ABSTRACT**

Forty-five $F_1$ hybrids were produced by crossing fifteen elite wheat cultivars used as pollen donor/ male parents with three *T. timopheevi* based male sterile lines used as female parents. Self-fertility status of these $F_1$ hybrids was studied. Two indexes, viz., number and percentage of seed development in bagged spikes of these forty-five $F_1$ hybrids, bagged before starting of anthesis, were used to determine the degree of fertility restored in the $F_1$ hybrids. Based upon a scale devised using the second index, i.e. percentage of seed development in bagged spikes, corresponding pollen parents were identified and classified as maintainer, partial maintainer, partial restorer or restorer. In the present study, WH 542 and KRL 99 were identified as partial restorers for CMS line WH 416A. Agronomic performances of the forty-five hybrids produced were also studied for days to heading, plant height, number of tillers per plant, number of florets per spike. $F_1$ cross-combinations, WH 416A X CBW 38, WH 416A X DBW 39, WH 416A X DBW 50 and WH 416A X NIAW 1188 were found remarkable for their agronomic performance.

***Keywords*:** Triticum timopheevi, CMS, hybrid seed productiom, fertility restoration

## Introduction

Wheat is one of the most important cereal crops of the world. It's wide adaptability to the different agro-climatic conditions and unique property of wheat flour and dough which allow its processing into a range of food products (Kant et al., 2014). With the increase in global population it is becoming of utter importance to produce sufficient amount of food grains for ensuring food security. Since the scope of area expansion is very limited, vertical expansion of productivity seem to be only solution to achieve our target of increased production of food grains. In this endeavour, exploitation of heterosis in crop plants seems to provide the needful respite. Although hybrid technology has remained very successful for several crops like rice (Singh et al., 2015), maize (Arya et al., 2015), pearl millet (Kumar et al., 2013) etc. but, successful exploitation of heterosis/ hybrid vigour on commercial basis is still awaited in important crop like wheat.

Since the autogamous nature of reproduction in wheat makes hybrid seed production a challenging task, it continues to be a major constraint in commercial level production of hybrid seed. Several types of pollination control strategies including genetic, cytoplasmic-genetic and chemically induced male sterility were tested for their use in hybrid seed production of wheat at commercial level.

With the discovery of cytoplasmic genetic male sterility (CGMS) in wheat by Kihara in 1951, hybrid wheat has attracted considerable research efforts

spanning several decades (reviewed by Blouet et al., 1999). Later, Wilson and Ross (1962) establish the existence of usable male sterility in wheat from the interaction of common wheat nucleus with *Triticum timopheevi* cytoplasm. Since then much work has been done using this species for the development of commercial hybrid. With the progress of research on cytoplasmic male sterility, male sterile cytoplasms of around 35 species were transferred to bread wheat genetic background. Among these, complete to partial sterility was induced by as many as, 20 species (Adugna et al., 2004). To date *Triticum timopheevi* cytoplasm (identified by Wilson & Ross, 1962) is considered the most effective one and has been used commercially (Mukai & Tsunewaki 1979), although to a limited extent. *T. timopheevi* zhuk. cytoplasm (also known as G cytoplasm) is now most widely used, because compared to other sources of cytoplasmic male sterility *T. timopheevi* provides several comparative advantages for it's uses in development of CGMS lines to be utilized for development of hybrid wheat. Most important of all is it's superior stability (Wilson & Ross, 1962) and high survival due to it's existence in nature for a very long time. Besides, it is unlikely for this cytoplasm to become vulnerable to biotic or abiotic stress compared to other sources of male sterile cytoplasms. An advantage of no ill effect of cytoplasm on agronomic performances of the hybrid also makes it better suited for it's uses in development of CGMS lines (Sage, 1976).

Wilson and Ross (1962) reported that the interaction of *T. timopheevi* zhuk. cytoplasm and the T. aestivum nucleus resulted in a complete and stable male sterility. *T. timopheevi* cytoplasm had no apparent adverse effects on plant growth and development. Nearly all hybrid wheat breeding motioned to be based on the *T. timopheevi* and its wide spread use has been largely the result of its apparently neutral effect on agronomic and quality characters. Only drawback is that it requires more than one gene for fertility restoration (Zhao, 1988).

## Materials and Methods

The study was executed in two separate experiments. The first experiment dealt with detection of ability of male parents for their ability of fertility restoration and classification of fifteen male parents into four categories *viz.,* maintainer, partial maintainer, partial restorer or restorer, based on the ability of these parents to induce development of seed in selfed spikes of corresponding $F_1$ hybrids. This experiment was carried out during the crop season, November, 2011-April, 2012. These forty-five hybrids were produced during crop season, November, 2010- April, 2011. The second experiment that was aimed at studying agronomic characteristics of the $F_1$ hybrids was carried out during November 2011-April, 2012. The hybrids were produced and both the experiments were performed at the experimental farm area of CCS Haryana Agricultural University, Hisar (29.1700° N, 75.7200° E), India, in sandy loam soil under normally grown, irrigated conditions.

For the first experiment forty-five $F_1$ hybrids were produced by crossing fifteen elite wheat cultivars used as pollen donor/ male parents and three *T. timopheevi* based male sterile lines used as female parents. Fifteen male parents were WH 147, WH 542, HD 2967, CBW 38, DBW 31, DBW 39, KRL 99, KRL 284, HD 2964, NIAW 1188, MP 1194, LB-PY 05-02, LBPY 05-04, RWP 206-33 and DBW 50. Three CMS lines used were WH 416A, Atilla A and PBW 445A. For the second experiment these forty-five $F_1$ hybrids were used as experimental materials.

Forty-five hybrids were grown in randomized block design with three replications in normal (timely sown) environment. Each genotype was grown in a plot of two meter long single row. The rows were placed 30 cm apart keeping 10 cm plant to plant distance. The other packages of practices were the same as recommended for normal environment. The fifteen male parents WH 147, WH 542, HD 2967, CBW 38, DBW 31, DBW 39, KRL 99, KRL 284, HD 2964, NIAW 1188, MP 1194, LB-PY 05-02, LBPY 05-04, RWP 206-33 and DBW 50 were grown in randomized block design with three replications in normal environment. Each genotype was grown in a plot of two meter long single row. The row was placed 30 cm apart keeping 10 cm plant to plant distance. The other packages of practices were the same as recommended for normal environment.

To produce $F_1$ hybrids, spikes were first covered with butter paper bags before their complete emergence from the leaf sheath of the flag leaf. The bags were then removed, lemma and palea of two lateral florets were trimmed, central florets were removed, and ¼ portion of the tip of spikes were removed. After these operations, the spikes were again covered with butter paper bags for ensuring parental identity of the hybrid seeds. After 3-4 days bags were opened and pollens from inflorescence of respective male parents were applied on them. After application of pollens externally, bags were again sealed to restrict entry of pollens from any undesired sources.

Five competitive plants from each $F_1$ hybrids were taken randomly from each replication and observations were recorded and mean values of each replication were calculated for number of grains per spike (bagged),

percentage of seed set (bagged), percentage of seed set (unbagged) and outcrossing (%). Percentages of seed set in bagged spikes were calculated as number of seeds setting per hundred bagged florets. Outcrossing percentage was calculated as the number of seeds developed in open spike per hundred florets, excluding the number of seeds developed in selfed spike of the same $F_1$ hybrid plant. Agronomic performance of the $F_1$ hybrids were also studied and observations were recorded for the following parameters *viz.,* days to heading, plant height, number of tillers per plant, number of florets per spike.

The mean values for these observations in each replication were calculated and subjected to analysis of variance (ANOVA) under Randomized Block Design (RBD) using statistical software OPSTAT (developed by Dr. O. P. Sheoran). For the purpose of suitability of applying ANOVA, to the percentage data, square root transformation and arc sine transformation was applied. Genetic variability for these agronomic traits was worked out in terms of range, mean, genotypic and phenotypic coefficient of variation (GCV and PCV), broad sense heritability, genetic advance under selection and genetic advance under selection as percentage of character mean.

## Results and Discussion

Data recorded in these two experiments are presented in Table 1 and Table 2 respectively for agronomic parameters and fertility restoration related parameters. Sum of square values from the analysis of variance for agronomic parameters of the hybrids are presented in table 3, which clearly revealed that all these characters varied significantly among the hybrids. Genotypic differences were significant for days to heading, plant height, number of tillers per plant and number of florets per spike.

Although the character days to heading had significant variability as tested in ANOVA, it showed a narrow range of 100.7 days to 103.07 days among the hybrids. This character showed low broad sense heritability and thus genetic advance under selection was less for this trait. Similarly, plant height also showed low broad sense heritability and genetic advance under selection. Plant heights of the hybrids were mostly around 100 cm, and it ranged between 90.4 cm to 146.4 cm. Number of tillers per plant and number of florets per spike showed high broad sense heritability and thus had high genetic advance under selection. This implies that there are scopes for further improvements for these traits and can be achieved by simple selection. Numbers of tillers per plants ranged from 16.06 to 35.06, while number of florets per spike among the hybrids ranged from 63.2 to 76.46. For the agronomic performances studied $F_1$ cross-combinations WH 416A X CBW 38, WH 416A X DBW 39, WH 416A X DBW 50 and WH 416A X NIAW 1188 was remarkable for their agronomic performance.

In the present study, floret fertility in terms of seed set under selfed condition was considered as an index to classify pollen parents among test crosses, into different categories. During this present study, it was fund that WH 542 and KRL 99 restored fertility but only partially, for CMS line WH 416A. Percentages of seed development in selfed spikes of test cross progenies from the crosses involving WH 542 and KRL 99 as pollen donor were 29.87% and 20.78% respectively. This difference between percentages of seed development in selfed spikes clearly indicates that there was difference between the two male parents for their ability of fertility restoration. The occurrence of fertility restoration to different degrees suggests that the importance and need for selection of satisfactory restorer lines for hybrids seed production, and at the same time indicates that fertility restoration in this case is not under control of a single dominant gene. Several research workers working on genetics of fertility restoration of wheat with sterile cytoplasmic background of *T. timopheevi* also reached similar conclusion (Mukai and Tsunwaki, 1979; Ikaguchi et al., 1999; Tsunewaki et al., 2002).

Another interesting point noted during the present study regarding the effect of fertility restorers. Although all the three CMS lines were derived from *T. timopheevi* cytoplasmic background, WH 542 and KRL99 showed partial fertility restoration against only one CMS line WH 416A. This unexpected result of fertility restoration only in WH 416A may be due to certain changes in it's organeller genome. Molecular studies related to endosymbiotic co-evolution of organeller genomes and nuclear genome revealed that several retrograde and anterograde regulatory systems and cross talks between several biochemical pathways in response to the external stimuli ultimately results in expression of male sterility and fertility restoration (Linke et al., 2005; Chase et al., 2006). Although determination of exact reason behind this weird behaviour was beyond the scope of present investigation, comparative analysis of mt DNA of these three lines and dissection of the mechanism of fertility restoration at molecular level might suggest probable reason.

Lack of satisfactory restoration is the major limiting factor to the development of wheat hybrids, which emphasizes the need to screen wheat germplasm in order

to identify effective restorers. In the present investigation WH 542 and KRL 99 behaved as partial fertility restorers, whereas rest thirteen behaved as sterility maintainer for CMS lines WH 416A, while all fifteen pollen parents behaved as sterility maintainers for CMS lines Atilla A and PBW 445A. Comparative representation of fertility restoration and sterility maintenance in the fifteen male parents are presented in Table 4.

Figure 1. Development of $F_1$ hybrid seeds. Florets were trimmed for easy access of externally applied pollens to the stigma. Photograph was taken after removing butter paper bag, used to ensure parental identity of the hybrid seeds produced

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Table 1. Mean values for agronomic traits of $F_1$ hybrids

| Male parents | CMS lines | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WH 416A | | | | Atilla A | | | | PBW 445A | | | |
| | DTH | PH | NTP | NFS | DTH | PH | NTP | NFS | DTH | PH | NTP | NFS |
| **WH 147** | 101.8 | 97.7 | 34.2 | 65.5 | 102.4 | 103.1 | 22.1 | 65.3 | 102.0 | 95.4 | 24.9 | 66.3 |
| **WH 542** | 103.1 | 95.7 | 24.3 | 65.1 | 101.6 | 125.6 | 21.3 | 63.5 | 102.6 | 90.4 | 26.9 | 64.5 |
| **HD 2967** | 100.9 | 106.8 | 24.4 | 65.1 | 102.8 | 105.6 | 21.7 | 63.4 | 101.0 | 113.4 | 27.9 | 65.3 |
| **CBW 38** | 100.7 | 101.8 | 27.9 | 63.6 | 101.0 | 109.4 | 26.3 | 63.9 | 102.7 | 130.3 | 18.1 | 63.2 |
| **DBW 31** | 102.6 | 113.0 | 23.5 | 63.5 | 102.4 | 106.7 | 24.5 | 65.5 | 102.6 | 105.6 | 32.0 | 65.3 |
| **DBW 39** | 100.7 | 110.5 | 21.0 | 64.7 | 102.6 | 144.8 | 18.3 | 65.3 | 102.7 | 113.3 | 16.2 | 66.3 |
| **KRL 99** | 101.0 | 108.0 | 25.3 | 63.5 | 102.4 | 97.88 | 25.0 | 64.0 | 102.6 | 107.6 | 25.8 | 64.5 |
| **KRL 284** | 100.8 | 103.6 | 18.9 | 64.4 | 101.8 | 111.5 | 23.7 | 66.3 | 102.4 | 131.7 | 30.7 | 64.0 |
| **HD 2964** | 101.4 | 115.5 | 25.5 | 63.4 | 102.8 | 105.0 | 26.6 | 66.4 | 102.7 | 106.3 | 18.7 | 65.5 |
| **NIAW 1188** | 102.5 | 119.1 | 26.7 | 76.5 | 102.7 | 103.4 | 31.1 | 65.3 | 102.8 | 146.4 | 27.9 | 65.3 |
| **MP 1194** | 102.8 | 124.0 | 21.5 | 65.3 | 102.4 | 107.6 | 29.6 | 66.5 | 102.4 | 114.4 | 26.3 | 63.40 |
| **LB-PY 05-02** | 102.2 | 139.5 | 24.3 | 73.2 | 102.8 | 120.6 | 16.3 | 63.4 | 101.0 | 141.8 | 18.1 | 63.5 |
| **LBPY 05-04** | 101.8 | 134.6 | 31.9 | 64.5 | 101.8 | 136.0 | 19.1 | 64.0 | 102.4 | 124.7 | 21.1 | 65.3 |
| **RWP 206-33** | 102.0 | 105.9 | 22.2 | 66.3 | 101.0 | 98.2 | 17.5 | 65.5 | 102.4 | 115.4 | 24.1 | 65.3 |
| **DBW 50** | 102.7 | 101.0 | 35.1 | 64.0 | 102.2 | 106.3 | 16.1 | 63.2 | 102.7 | 111.6 | 23.4 | 64.4 |
| **CD at 5%** | 1.01 | 12.67 | 2.01 | 0.39 | 1.01 | 12.67 | 2.01 | 0.39 | 1.01 | 12.67 | 2.01 | 0.39 |

DTH = Days to heading, PH = Plant height (cm), NTP = Numbers of tillers per plant, NFS = Number of florets per spike

Table 2. Mean values for fertility restoration related traits of $F_1$ hybrids

| Male parents | CMS lines | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WH 416A | | | | Atilla A | | | | PBW 445A | | | |
| | NGS (UB) | NGS (B) | SSP (B) | SSP (UB) | NGS (UB) | NGS (B) | SSP (B) | SSP (UB) | NGS (UB) | NGS (B) | SSP (B) | SSP (UB) |
| **WH 147** | 12.93 | 0.56 | 0.86 | 19.74 | 17.47 | 0.00 | 0.00 | 26.76 | 17.73 | 0.00 | 0.00 | 26.73 |
| **WH 542** | 28.27 | 19.46 | 29.87 | 43.40 | 11.80 | 0.00 | 0.00 | 18.56 | 12.20 | 0.00 | 0.00 | 18.91 |
| **HD 2967** | 19.33 | 0.00 | 0.00 | 29.71 | 14.00 | 0.25 | 0.39 | 22.08 | 14.03 | 0.00 | 0.00 | 21.51 |
| **CBW 38** | 18.80 | 0.00 | 0.00 | 29.57 | 10.33 | 0.00 | 0.00 | 16.20 | 21.93 | 0.00 | 0.00 | 34.72 |
| **DBW 31** | 1.60 | 0.00 | 0.00 | 2.52 | 15.33 | 0.00 | 0.00 | 23.43 | 2.07 | 0.00 | 0.00 | 3.17 |
| **DBW 39** | 9.73 | 0.00 | 0.00 | 15.05 | 16.40 | 1.05 | 1.61 | 25.15 | 10.40 | 0.00 | 0.00 | 15.69 |
| **KRL 99** | 26.67 | 13.20 | 20.78 | 41.99 | 17.13 | 0.00 | 0.00 | 26.77 | 18.33 | 0.00 | 0.00 | 28.41 |
| **KRL 284** | 12.13 | 0.00 | 0.00 | 18.84 | 10.13 | 0.00 | 0.00 | 15.28 | 16.47 | 0.00 | 0.00 | 25.74 |
| **HD 2964** | 15.07 | 0.00 | 0.00 | 23.77 | 13.93 | 0.00 | 0.00 | 20.98 | 14.33 | 0.00 | 0.00 | 21.89 |
| **NIAW 1188** | 11.07 | 0.78 | 1.02 | 14.47 | 14.47 | 0.00 | 0.00 | 22.16 | 17.93 | 0.00 | 0.00 | 27.50 |
| **MP 1194** | 13.73 | 0.00 | 0.00 | 21.04 | 18.93 | 0.00 | 0.00 | 28.47 | 19.60 | 0.00 | 0.00 | 30.92 |
| **LB-PY 05-02** | 20.90 | 0.00 | 0.00 | 28.55 | 11.93 | 0.00 | 0.00 | 18.82 | 15.63 | 0.50 | 0.79 | 24.62 |
| **LBPY 05-04** | 15.33 | 0.00 | 0.00 | 23.81 | 15.80 | 0.00 | 0.00 | 24.70 | 18.20 | 0.00 | 0.00 | 27.89 |
| **RWP 206-33** | 15.40 | 0.00 | 0.00 | 23.26 | 8.60 | 0.00 | 0.00 | 13.13 | 14.87 | 0.00 | 0.00 | 22.78 |
| **DBW 50** | 16.73 | 0.00 | 0.00 | 26.14 | 19.73 | 0.00 | 0.00 | 31.23 | 16.57 | 0.35 | 0.54 | 25.72 |

NGS (UB) = Number of grains/spike (un-bagged), NGS (B) = Number of grains/spike (bagged), SSP (B) = Seed setting Percentage (bagged), SSP (UB) = Seed setting Percentage (un-bagged)

Table 3. Analysis of variance for agronomic traits of $F_1$ hybrids

| Sources of variation (SOV) | Degrees of freedom (df) | Mean squares | | | |
|---|---|---|---|---|---|
| | | Days to heading (days) | Plant height (cm) | Number of tillers per plant | Number of florets per spike |
| Replication | 2 | 1.09 | 77.52 | 1.30 | 1.02 |
| Genotype | 44 | 1.50** | 700.08** | 69.25** | 16.67** |
| Error | 88 | 0.39 | 60.72 | 1.52 | 0.61 |

** $p < 0.01$

Table 4. Classification of wheat cultivars for their ability of fertility restoration

| Pollen parents | Seed setting under selfing (%) in CMS lines | | |
|---|---|---|---|
| | WH 416A | Atilla A | PBW 445A |
| **WH 147** | 0.86 (PM) | 0.00 (M) | 0.00 (M) |
| **WH 542** | 29.87 (PR) | 0.00 (M) | 0.00 (M) |
| **HD 2967** | 0.00 (M) | 0.39 (PM) | 0.00 (M) |
| **CBW 38** | 0.00 (M) | 0.00 (M) | 0.00 (M) |
| **DBW 31** | 0.00 (M) | 0.00 (M) | 0.00 (M) |
| **DBW 39** | 0.00 (M) | 1.61 (PM) | 0.00 (M) |
| **KRL 99** | 20.78(PR) | 0.00 (M) | 0.00 (M) |
| **KRL 284** | 0.00 (M) | 0.00 (M) | 0.00 (M) |
| **HD 2964** | 0.00 (M) | 0.00 (M) | 0.00 (M) |
| **NIAW 1188** | 1.02 (PM) | 0.00 (M) | 0.00 (M) |
| **MP 1194** | 0.00 (M) | 0.00 (M) | 0.00 (M) |
| **LB-PY 05-02** | 0.00 (M) | 0.00 (M) | 0.79 (PM) |
| **LBPY 05-04** | 0.00 (M) | 0.00 (M) | 0.00 (M) |
| **RWP 206-33** | 0.00 (M) | 0.00 (M) | 0.00 (M) |
| **DBW 50** | 0.00 (M) | 0.00 (M) | 0.54 (PM) |

**Note:**

| Nuclear cytoplasmic interaction | Percentage of seed setting in selfing |
|---|---|
| Maintainer (M) | 0% |
| Partial maintainer (PM) | >0% to 20% |
| Partial restorer (PR) | >20% to 80% |
| Restorer (R) | >80% to 100% |

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# Tea (*Camellia sinensis*) Cultivation and Breeding in Turkey: Past and Present Status

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**ABSTRACT**

Tea was introduced into Turkey with the efforts of Zihni Derin and Ali Rıza Erten at the end of the 1930s. ÇAYKUR (Çay İşletmeleri Genel Müdürlüğü/ General Directorate of Tea Enterprises), a governmental company, is responsible for tea production and breeding in Turkey. The company developed tea clones and distributed to local farmers. But, after the 1950s multiplication of tea with seeds arised in Turkey. Assumedly, nearly the whole plantations in Turkey are multiplicated with seeds, which tradition is ongoing. ÇAYKUR selected nearly 40 clones which are preserved in the gene pool of ÇAYKUR. During the last 40 years, the establishment, pruning, harvest and transfer of harvested tea leaves etc. emerged to a insensible situation. These problems have to be solved for an better tea cultivation in Turkey. On the other hand, the understanding of the development of the genetic collection of a strategically important crop such as tea (*Camellia simensis* O. Kuntze) is very important for its breeding and improvement of advanced research facilities. This review summarises the available information on tea cultivation and tea breeding in Turkey. Tea cultivation in Turkey contributes significantly to the economic income of local farmers in the North-East Black Sea region. The major breeding achievement was the selection of clones, which were selected from present tea gardens. After adaptation of superior tea clones in classical and organic tea cultivation, tea cultivation and breeding will make an important progress in Turkey.

***Keywords*****:** Camellia sinensis, tea, tea production, tea breeding

## Introduction

Tea production are practised in the Eastern Black Sea Region, in a zone beginning from the Georgian border up to the Fatsa district in Ordu. In this region, tea production is mainly located in Rize, Ordu, Giresun and Trabzon (Anonymous 2015). If we are considering the tea production areas in the world, these regions are located in the top zone. In Asian countries like China, India and Sri Lanka temperature does not falls up to minus degree in tea production areas and tea production is covering the whole year. But in our country, where we can feel four climates tea plantations are in fallow four six months. The fact that snow falls on Turkish tea plantations bring them an extra important characteristic. Because of this character, pesticides are not applicated in our tea production areas. That's why, Turkish tea has "the most natural tea" characteristic as compared to other teas in the world.

The biggest advantage of Turkish tea sector is that pesticides are not used for its cultivation. The winter conditions decease pests in natural means as it snow in Rize province, situated in the north east of Turkey. As a result of that, there is no need to use any pesticide. Actually, a very small populations of pests have been seen in Rize province, and they do not reach up to the economic threshold level require to use pesticides. Two important parameters prevent the production of organic tea in general. One of them is the pesticide and the other

one is chemical fertilizers. All of the tea, produced in Turkey, will be organic product if it is used organic fertilizers instead of chemical ones, as the Turkish tea industry has already not been used pesticides. This feature provides a great advantage to Turkish tea sector (Saklı 2011).

**History of Tea in Turkey**

In 1930s, the government decided to start a agricultural programme for poor farmers in the Northern Black Sea Region. After 1940s, tea cultivation started primarily in Turkey and the first aim was to meet the needs of the domestic demand. In beginning, it was very difficult to introduce the new crop, tea in the mentioned area. The general assumption of the people about the starting efforts of tea cultivation was negative at that time. But against this, the local tea industry and tea trade in Turkey established to a successful business. At the meantime, Turkey has established an important place in world tea production (Klasra et al., 2007).

We can see that tea cultivation was first started in Batum (Republic of Georgia). Russians imported seedlings from China and established plantations in the neighbouring of the Eastern Black Sea region of Turkey in the last quarter of 19$^{th}$ century. After a successful tea cultivation in Georgia, people stated that the same could be applied at the North East Part of Turkey.

After a succcessful introduction of tea by Russians in Batum imaginations arised that tea cultivation can be a option for local farmers in Turkey. First attempt was started to cultivate tea in Bursa and seedlings were imported in 1888 from China and Japan (Tekeli 1976). But because of unfavourable conditions for tea in Bursa, it was stated that tea plants needed a very specific environmental conditions to make an economic production.

Thereafter, Mr. Ali Riza Erten searched for the feasibility of some other suitable locations within the Turkey for tea cultivation and started extensive visits to Rize, Artvin, Ardahan (Turkey) and Batum (Georgia) in the Eastern Black Sea region (Kakuzu 1944; Kacar 1986a,b). He made a comprehensive analysis and stated that the ecology of Rize, Artvin and Ardahan was very similar to Batum. After his analysis, he give a report to the government that tea cultivation could be feasible at Rize and surroundings (Hatipoğlu 1934 a,b; Arar 1969).

In Turkey, tea cultivation first started by law in 1924 and the Tea Research Institute was established. In 1947, the first plant for processing green tea leaves was opened in Rize. Rize, Ordu, Giresun, Trabzon and Artvin are the provinces in which tea is produced.

In order to supply better service, parallel to the growth in this sector, an economic enterprise, ÇAYKUR (General Directorate of Tea Enterprises) was established in 1971 and was fully authorized as a state monopoly in the tea business. In 1984, with the abolishment of the monopoly in the tea sector, private enterprises were also given the rights of procurement, processing and marketing (Anonymous 2017).

**Tea Production in Turkey**

Although, the tea business in Turkey is a relatively new activity compared with the other producer countries, tea cultivation and the industry have shown very important improvement in a short time. While the production of dried tea was below 25, 000 tons in the 1950's, this figure reached significant quantities in recent years. Today, Turkey holds a significant place among the world's largest producer countries with a share of 3%. According to the Food and Agriculture Organization (FAO) statistics, Turkey ranks 8$^{th}$ place in the world production area of tea after China, India, Sri Lanka, Kenya, Indonesia, Vietnam and Myanmar.Regarding world tea production in the world Turkey ranks at the 5$^{th}$ place after China, India, Kenya, Sri Lanka and Vietnam (Table 2).

In Turkey, tea production is located in the North-East Black Sea Region. The tea plantations are distributed in the cities Artvin, Rize, Trabzon, Ordu and Giresun (Figure 1).

Table 3 shows the distribution of tea production areas according to related cities. The main tea production area is Rize with 65.96%. followed by Trabzon, Artvin, Giresun and Ordu. Parallelly, the number of tea farmers are following the same ranking.

**Tea Plantation Areas in Turkey**

Tea plantation areas are regulated in Turkey by law. In the Official Gazette of Turkey the judgment "Determination of tea plantation areas and authorization of tea producing farmers" was printed according to the No. 2. Article of the Tea Law and according to the writing of the Ministry of Food, Agriculture and Livestock. Based on this legal decision tea plantation areas are restricted with some cities and districts which are depicted in Table 4.

**ÇAYKUR**

ÇAYKUR was founded in 10.10.1983 as a government institution. Çaykur and its Atatürk Research Institute for Tea and Horticultural Cultures (Atatürk Çay ve Bahçe Kültürleri Araştırma Enstitüsü Müdürlüğü) are responsible for tea cultivation and breeding in Turkey.

**Situation of Tea Research in Turkey**

ÇAYKUR is a governmental institution which is responsible for tea research in Turkey. As mentioned before, different research schemes were conducted for farmers as their needs. In the last 5 years, two new tea research centers were founded. ÇAYMER and the Tea Research and Application Center of the Recep Tayyip Erdogan University.

**Tea Research Institutions in Turkey**

**1. Rize Tea Research Institute**

The business of the Rize Tea Research Institute is developing tea cultivation according to the agricultural policy of Turkey, creating investment, assisting funding, capital stock, achieving maximum benefit under free market conditions; and producing, import and export of all kinds of tea with supplement of necessary raw material, including all areas related to enhance the competitive capacity of the organization in inner and foreign markets.

**2. ÇAYMER**

In the context of the operational programme of regional competitiveness ÇAYMER (Rize Çay Araştırma ve Uygulama Merkezi/Rize Tea Reserach and Application Center) was signed an initiated in 14.01.2011 with support of Commodity of Exchange Market, Recep Tayyip Erdoğan University and Rize Office of Governor. This Project is financed by the EU and Turkish government. The general aims of this project are to improve the competitive capacity and production quality of the tea sector concentrated in Rize and surroundings, to strengthen the common Research and Development, innovation and infrastructure of business development from which the tea producer SMEs can get profit. The expectation is to provide high quality service to SMEs with improved infrastructure and to reach that 150 SMEs get service from this center. Further, this center aims to increase the added-value of tea quality with increasing tea product varieties and by-products, because, the present added-value of tea quality is low.

**3. Tea Research and Application Center of Recep Tayyip Erdogan University**

This center was initiated in 2017. The aims of this center are to conduct tea research at national and international level, to collaborate with international institutions, to appraise obtained results with farmers, and to participate in national and international congresses and cover all issues regarding tea production, education and further issues. Another aim is to support M.Sc and Ph.D. research work of students.

**BREEDING EFFORTS ON TEA IN TURKEY**

Firstly, the responsibility of breeding work on tea was assigned to Çaykur. But up to now, only clonal selection studies were carried out in Turkey, which are explained below in detail.

**Clones Selection Work in Turkey**

As we know, clones are genetically uniform copies of the donor plant and they display uniform yield and quality. After intensive mass clonal multiplication, the aims are to cultivate clones having high yield and resistance to pathogens etc.. However, the genetically diverse populations don't give homogeneous quality but these populations are less prone to environmental conditions (Bandyopadhyay and Das 2008). As mentioned before, ÇAYKUR developed tea clone since the 1940s and distributed them to farmers. But because of repudiation of the new crop a huge number of farmers removed the established plantations and proceeded with conventional plants.

After the recognition that tea has the potential as an economically important plant, tea establishment flourished again, but the farmers used seeds in the establishment of new plantations. Because of the cross-pollinating character of the tea plant, huge noticeable variation arised in Turkish tea plantations, which presents a good base for clonal selection. Wide genetic variability is necessary, because it is a resource for fighting against diseases, pests and the key factor to adapt changing environment (Barua 1963; Wachira et al., 1995).

Before the replacement of present tea plantations with new, high yielding genotypes it is necessary to preserve present, high diversity displaying populations as *in situ* conservation sites.

In Turkey, most of the tea plantations were established by using seeds; continuous seed propagation has produced populations with different yield and quality properties, reflecting wide genetic variation. Clonal selection studies were conducted in the Black Sea region and several promising tea clones such as 'Tuglali-10', 'Derepazari-7', and 'Pazar-20' have been identified (Öksüz 1987). Clones named Muradiye, Gündoğdu, Fener3, Enstitü1, Enstitü2, Hamzabey, Hayrat, Çayeli, Ardeşen, Fındıklı, Pazar and Iyidere followed later. Basically, clonal selection work was done by ÇAYKUR in this region. The full list of selected clones is given in Table 5.

**TEA RESEARCH FACILITIES IN TURKEY**

**1. Improvement of Tea Quality**

In 2016, the Research Project on "Improvement of Tea Quality" funded by DOKAP was initiated. The aim of this Project was firstly the establishment of a quality analysis laboratory for the Faculty of Agricultural Sciences in Rize, secondly the determination of biochemical, morphological and molecular variability in whole tea plantation areas and at least the creation of a mini tea factory for the mentioned Faculty of Recep Tayyip Erdoğan University.

**2. Use of Organic Fertilizers in Tea Cultivation**

2a. Research Project of the Faculty of Agriculture and Natural Sciences, Field Crops Department founded by the university was initiated. In present tea plantations, 21 different organic fertilizers were tested at 8 locations to observe their effects on yield.

2b. In 2018, the Project "Effect of Organic Fertilizers on Parameters with Medicinal value in Tea"

founded by DOKAP was initiated based upon the first mentioned Project. Additionally, one location on the organic tea production area in Hemşin was added to the mentioned locations.

**3. Molecular marker work**

Before starting a breeding programme, present genetic variation needs to be characterised. The molecular work was carried out by different researchers namely Kafkas et al., (2009) and Beriş et al., (2001, 2005, 2016) by using different marker systems to determine genetic variation in selected tea clones.

**4. Plant Growth Promoting Bacteria as Organic Fertilizer**

The research on utilization of plant growth promoting bacteria in organic tea production was conducted by Çakmakçı et al., (2012, 2013, 2016).

## FUTURE TRENDS FOR TEA IMPROVEMENT IN TURKEY

As mentioned before tea plantations in Turkey are established using seeds. Therefore, huge heterogenity exists in Turkish tea plantations. Also as mentioned before, only clonal selection work was done beginning from the 1980s, but no adaptation and yield trials were conducted. Only the mentioned Project aimed to characterize present plantations on morphological, biochemical and molecular level.

Primarily, to improve tea production economic status in Turkey, there is need for further improvement in tea production practices. Besides, there is need for mass collection of germplasm in all tea producing areas in Turkey to establish a national tea germplasm collection, where the co-operation of ÇAYKUR and the local University and related agricultural faculty is required. The clonal selection work aims to generate selected clones using tissue culture were present in the past. Although, it is possible to characterize this selected material on the basis of morphological descriptors, but actually, the clearest and basic distinguishing tool are molecular markers.

**Possible research studies for tea in Turkey:**

**1. Tea Seed Oil**

All species of the *Camellia* genus produce an oleaginous seed. Crude edible oil was produced from tea seed in native mills in West Bengal, Himachal Pradesh and Assam and in the Northern region of Indo-china (Owuor et al., 1985). Tea seed oil has been produced on commercial scale in China where in 1958, 180,000 tons of the oil) was produced (Sengupta et al., 1986).

The oil extracted from the seeds of *Camellia* species both cultivated as well as other species is termed as tea seed oil. Though, *C. sinensis* is cultivated mostly for producing tea at commercial level, but oil is not usually obtained from this specie. Commercial production of oil is derived from species like *C. sasanqua*, *C. japonica*, *C. tenuifolia* and *C. oleifera*. Seeds of different *Camellia* species contain 20-70% oil which is comparable to olive (*Olea europaea*) oil in its quality. It could be, therefore, utilized as a potential substitute for olive oil as well as other edible oils.

The tea seed oil is yellow coloured, free flowing, has pleasant odour and can be stored for 3 months at room temperature without losing its quality (Roberts and De Silva 1972). Fatty acid composition of *C. sinensis* seed oil consisted of 21.5% palmitic acid, 2.9% stearic acid (Rajaei et al., 2008), 56% oleic acid, 22% linoleic acid and 0.3% linolenic acid (Sahari et al., 2004). The major fatty acid (50% of the total oil) in the *C. sinensis* seed oil was oleic acid (Rajaei et al., 2005). Therefore, with regard to oleic acid, *C. sinensis* seed oil can be ranked between sunflower and olive oil (Sahari et al., 2004).

**2. Renewal of Tea Plantations**

We know that present tea plantations were established using seeds. Because of the cross-pollination behaviour of this plant variation arised in local tea plantations. This leads to aberrance development and harvest of tea plants, which also leds to problems in processing because harvested tea leaves are not homogenous. Therefore, superior tea clones have to be selected and yield trials to be conducted in different environments and at different altitudes. After obtained results, the best performing clones should be multiplicated using cuttings or tissue culture technique. The renewal of present tea plantations will be an important next issue in the future.

**3. Organic Tea Cultivation**

In Turkey, tea cultivation begun first in 1938. After 1960s intensive chemical fertilizer use arised. Parallel to the developments in the world ÇAYKUR initiated in 2003 studies to increase organic tea farming in Turkey (Seyis et al., 2018). Within the context of organic tea farming Borçka/Artvin and Çamlıhemşin and Hemşin/Rize was chosen as organic tea production areas. In 2006, ÇAYKUR founded the "Organic Tea Farming Commission" to organize studies regarding organic tea farming and production and to determine a road map for organic tea.

Organic tea production increased from 378 da in 2007 up to 38,034 da in 2016. Also, a number of organic tea farmers increased from 135 in 2007 up to 11,786 in 2016 (Table 4). In Table 5, processed organic black and green tea amounts are given. The total quantity of purchased wet tea, processed black and green tea have been increased from 2009 up to 2016. There is a remarkable increase in organic tea production in Turkey during the last decade. Organic black tea production increased more as compared to organic tea production.

### 4. Development of a National Tea Germplasm Collection

Development and identification of germplasm accessions are important. They can be included in the breeding programmes, which is vital to broaden the gene pool of the cultivated tea plant. The relevant use of such collections depends on huge extent of the knowledge and understanding of the relevant characteristics and the genetic diversity of the collection. Therefore, the knowledge about different characteristics like morphological, agronomical and biochemical ones are important to use such material effectively and to use them in crop improvement programmes (Kottawa-Arachchi 2013).

In Turkey, nearly all tea plantations were multiplied with seed. Because of the cross-pollinating character of the tea plant huge variations have been arised in local tea plantations. The heterozygous character of present tea plantations leds to differentiation in harvest time and especially in the chemical content of harvested leaves.

Therefore, superior tea clones have to be selected from Turkish tea plantations to support tea breeding programmes. Such a Project will cover the coming 50 years of tea breeding.

## Conclusion

Tea, a very important crop regarding the income of local farmers in the Northern Black Sea Region of Turkey, is multiplicated by farmers using seeds in the last 50 years. Because of this, huge variation was created in present tea plantations which offers a good base for the beginning of selection of superior clones, which of course should be characterised on molecular level using relevant markers and marker systems.

After the fulfilment of the selection process, the cultivation procedures should be reintegrated by farmers, because different and wrong practices were developed from farmers side. This could be achieved by educational seminars throughout the year. Of course, success could be achieved with the cooperation of farmers, the local university and local governmental and non-governmental institutions.

Table 1. Tea production areas in the world

| Countries | Tea area (thousand ha) |
|---|---|
| **China** | 1984 |
| **India** | 604 |
| **Sri Lanka** | 222 |
| **Kenya** | 203 |
| **Indonesia** | 119 |
| **Vietnam** | 115 |
| **Myanmar** | 83 |
| **Turkey** | 76 |
| **Other countries total** | 382 |

Source: FAO (2018)

Table 2. Tea production in the world

| Countries | Yield (tonnes) |
|---|---|
| **China** | 2.414 |
| **India** | 1.252 |
| **Kenia** | 473 |
| **Sri Lanka** | 349 |
| **Turkey** | 243 |
| **Vietnam** | 240 |
| **Endonesia** | 144 |
| **Japonya** | 80 |
| **Iran** | 75 |

Source: FAO (2018)

Table 3. Tea plantation area and number of farmers

| City | Tea area (ha) | % | Number of farmers | % |
|---|---|---|---|---|
| **Rize** | 555.146 | 66.49 | 132.264 | 61.75 |
| **Trabzon** | 162.469 | 24.09 | 51.595 | 24.09 |
| **Artvin** | 96.281 | 11.53 | 20.398 | 9.52 |
| **Giresun-Ordu** | 20.993 | 2.51 | 9.919 | 4.63 |
| **Total** | 834.889 | 100.00 | 214.160 | 100 |

Source: Anonymous (2017)

Table 4. Tea plantation areas in Turkey

| Cities | Districts |
|---|---|
| Artvin | Arhavi, Borçka and Hopa |
| Giresun | Çanakçı, Espiye, Eynesil, Görele, Güce and Tirebolu |
| Rize | Center and all districts |
| Trabzon | Center, Araklı, Beşikdüzü, Çaykara, Dernekpazarı, Hayrat, Köprübaşı, Of, Sürmene and Vakfıkebir |

Figure 1. Tea production areas at the Black Sea Region


Table 5. Selected clones by the Tea Research Institute in Rize/Turkey

| Name | Province of origin | Selected by |
|---|---|---|
| **Ardeşen** | Rize | Rize Tea Research Institute |
| **Ali Rıza Erten** | Rize | Rize Tea Research Institute |
| **Çayeli-46** | Rize | Rize Tea Research Institute |
| **Çiftekavak** | Trabzon | Rize Tea Research Institute |
| **Derepazarı-7** | Rize | Rize Tea Research Institute |
| **Derepazarı-32** | Rize | Rize Tea Research Institute |
| **Enstitü-1** | Rize | Rize Tea Research Institute |
| **Çaykur-1** | Rize | Rize Tea Research Institute |
| **Çaykur-2** | Rize | Rize Tea Research Institute |
| **Çaykur-3** | Rize | Rize Tea Research Institute |
| **Çaykur-4** | Rize | Rize Tea Research Institute |
| **Enstitü-2** | Rize | Rize Tea Research Institute |
| **Enstitü-9** | Rize | Rize Tea Research Institute |
| **Enstitü-61** | Rize | Rize Tea Research Institute |
| **Fındıklı** | Rize | Rize Tea Research Institute |
| **Fener-3** | Rize | Rize Tea Research Institute |

*Continuing table 5*

| Name | Province of origin | Selected by |
|---|---|---|
| **Gündoğdu-3** | Rize | Rize Tea Research Institute |
| **Gündoğdu-19** | Rize | Rize Tea Research Institute |
| **Güneysu-26** | Rize | Rize Tea Research Institute |
| **Hamzabey** | Rize | Rize Tea Research Institute |
| **Hayrat** | Trabzon | Rize Tea Research Institute |
| **İyidere** | Rize | Rize Tea Research Institute |
| **Kalkandere-10** | Rize | Rize Tea Research Institute |
| **Kalkandere-12** | Rize | Rize Tea Research Institute |
| **Kömürcüler** | Rize | Rize Tea Research Institute |
| **Kolhida** | Trabzon | Rize Tea Research Institute |
| **Kömürcüler-1** | Rize | Rize Tea Research Institute |
| **Kömürcüler-4** | Rize | Rize Tea Research Institute |
| **Muradiye-10** | Rize | Rize Tea Research Institute |
| **Of-25** | Trabzon | Rize Tea Research Institute |
| **Of-37** | Trabzon | Rize Tea Research Institute |
| **Of-53** | Trabzon | Rize Tea Research Institute |
| **Of-66** | Trabzon | Rize Tea Research Institute |
| **Of-264** | Trabzon | Rize Tea Research Institute |
| **Pazar-14** | Rize | Rize Tea Research Institute |
| **Pazar-20** | Rize | Rize Tea Research Institute |
| **Pazar-42** | Rize | Rize Tea Research Institute |
| **Sürmene-1** | Trabzon | Rize Tea Research Institute |
| **Sürmen-6** | Trabzon | Rize Tea Research Institute |
| **Sürmene-24** | Trabzon | Rize Tea Research Institute |
| **Sürmene-29** | Trabzon | Rize Tea Research Institute |
| **Sürmene-39** | Trabzon | Rize Tea Research Institute |
| **Tuğlalı-10** | Rize | Rize Tea Research Institute |
| **Üniversite** | Rize | Rize Tea Research Institute |
| **Üniversite 2** | Rize | Rize Tea Research Institute |
| **Zihni Derin** | Rize | Rize Tea Research Institute |

Sources: Anonymous, (2017)

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This result was in agreement with result of Sahin and Yildirim (2004).

Similar effect has been widely studied prior to this study (Eser 1991; Bagci et al. 1995; Uzun and Yol 2013).

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Journal article:

Toker C (1998). Adaptation of kabuli chickpeas (*Cicer arietinum* L.) to the low and high lands in the West Mediterranean region of Turkey. Turk J Field Crop 3:10-15.

Toker C and Canci H (2003). Selection of chickpea (*Cicer arietinum* L.) genotypes for resistance to ascochyta blight [*Ascochyta rabie*i (Pass.) Labr.], yield and yield criteria. Turk J Agric For27: 277-283.

Toker C, Canci H and Ceylan FO (2006). Estimation of outcrossing rate in chickpea (*Cicer arietinum* L.) sown in autumn.Euphytica 151: 201-205.

Article by Digital Object Identifier (DOI) number:

Yasar M, Ceylan FO, Ikten C and Toker C (2013). Comparison of expressivity and penetrance of the double podding trait and yield components based on reciprocal crosses of kabuli and desi chickpeas (CicerarietinumL.). Euphyticadoi:10.1007/s001090000086

Book:

Toker C (2014). Yemeklik Baklagiller. BISAB, Ankara.

Book chapter:

Toker C, Lluch C, Tejera NA, Serraj R and Siddique KHM (2007) Abiotic stresses. In: Chickpea Breeding and Management,Yadav SS, Redden B, Chen W and Sharma B (eds.),CAB Int. Wallingford, pp: 474-496.

Online document:

FAOSTAT J (2013) http://faostat.fao.org/site/567/default.aspx# anchor. Accessed 15 May 2013.

Dissertation (Thesis):

Yasar M (2012). Penetrance and expressivity of double podding characteristic in chickpea (Cicer arietinum L.). Dissertation, Akdeniz University, Antalya.

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Abbreviations

Abbreviations should be defined at first mention and used consistently.

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