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## Heterosis and heterobeltiosis studies on yield and yield components of some Turkish poppy hybrids (*Papaver somniferum* L.)

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### ABSTRACT

Poppy (*Papaver somniferum* L.) is highly strategic and sensitive economic crop. A set of 7 potential poppy parent lines and cultivars along with their 42 reciprocal hybrids was made to collect information on extent of heterosis and heterobeltiosis for selection of better parents for capsules, seeds, morphine and total alkaloids yield. The study was carried out during 2012–13 and 2013–14 growing seasons. Heterosis and heterobeltiosis values of capsule yield varied between –19.59% to 94.87% and –28.84% to 87.71%, seed yield varied between –14.75% to 83.61% and –21.21% to 78.67%, morphine yield varied between –26.87% to 174.35% and –32.68% to 137.70% total alkaloid yield ranged –23.92% to 160.50% and –32.46% to 145.67% respectively. It was noted that TMOT × Ofis-8 and TMOT × “2010” were the best hybrids in terms of capsule, seed, morphine and total alkaloid yield. Whereas, the maximum heterotic depression for capsules, seeds, morphine and alkaloid yield was noted for N-442 × TMOT hybrids. The study showed good scope for commercial exploitation of heterosis and isolation of pure lines among progenies of heterotic F1 hybrids. Thus, taking an overview of the results of this study it can be suggested that, future studies should focus on TMOT, Ofis-8, “2010” and N 442 cultivars for breeding new high and low morphine cultivars in hybridization programs profitably.

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### 1. Introduction

Poppy (*Papaver somniferum* L.) is the most economic narcotic plant species among genus *Papaver*. Its cultivation is permitted by special legislation in the world (Kapoor, 1995). *P. somniferum* is an annual and herbaceous plant that depends on climate and growing conditions. Turkey is a diversity center for opium poppy. Abundance of landraces due to observed morphological and molecular diversity in Turkish germplasm make it a valuable genetic resource (Mihalik, 2006; Celik et al., 2016) This variability is very obvious for morphine content, plant height, and capsule index (Güçlü et al., 2014; Celik et al., 2016). There are 39 *Papaver* species, 19 annual and 20 multi-annual (2 subspecies and 7 varieties) mentioned in the Flora of Turkey (Davis et al., 1988). However, latest revisions show 58 taxa and 22 subspecies, 15 of which are endemic (Davis et al., 1988; Kapoor, 1997; Anon, 2015).

Its flowers' color changes from purple, pink to white; has closed capsules and grow up to 60–200 cm (Bernath, 2006; Valizadeh, 2015). Morphine, codeine, thebaine, papaverine and narcotine

alkaloids that are produced by poppy are used as an important raw material for pharmacy to make pain killers, cough suppressants and spasm reduction drugs that are used in addition to extracted oil. It is also used as ornamental plant for attractive purple, pink to white colored flowers with closed capsules that grow up to 60–200 cm (Valizadeh, 2015). All these characteristics make poppy a versatile crop plant (Gümüüşçü 2002; Anon, 2013).

The poppy-plant is grown in Turkey by small farmers under license, who usually plant no more than 5–10 ha of land without using machinery except ox-ploughs on family type farms. It brings money to the farmers before grain harvest to meet expenses to run household and the main harvest (Anon, 2016a).

Poppy seed production started under controlled conditions during 1933 for the first time in Turkey that continued uninterrupted until 1971 primarily for collection of latex/opium gum for use in pharmaceutical industry. Thereafter, poppy cultivation remained banned until 1974. Subsequently, poppy cultivation was allowed in the Aegean and the Central Anatolian regions with prohibition to scratch and collect gum from the capsules and plants during 1980 to produce morphine (Anon, 2016b). The United Nations has given Turkey a limit of 70,000 ha to grow poppy under controlled conditions. Its cultivated area and yield fluctuates as influenced by environmental conditions; but is enough to meet >40% needs of many pharmaceuticals companies in the Northern hemisphere.

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The expected opiate raw materials rich in morphine equivalent was 164 t in 2011 that fluctuated to 14 t in 2012, 67 t in 2013, 43 t in 2014, 113 t in 2015 and 96 t in 2016. No increase or decrease in area cultivated with opium poppy rich in morphine, thebaine and codeine was noted in Turkey from 2011 to 2016 (INCB, 2016). France, Turkey, Australia and Spain together produced about 80 per cent of global production of opiate raw materials rich in morphine in 2015.

Morphine, codeine, thebaine, papaverine and narcotine alkaloids that are produced by poppy are used as an important raw material for pharmacy to make painkillers, cough suppressant and spasm reduction drugs that are used in addition to extracted oil (Gümüştü, 2002; Bernath, 2006; Németh-Zámboi et al., 2011; Anon, 2013). These days besides traditional methods of breeding, molecular assisted selection techniques are in vogue at almost every place working on poppy breeding for development of high morphine or morphine less cultivars to meet ever-increasing global demand for use in pharmaceutical industry and make it widely available for use in foods and for ornamental purpose respectively. The breeding of such cultivars can help opium farmers to sow food grade poppy unrestricted without any license or permit. Food grade poppy has high demand in the world market and breeding of such cultivars can help in regular meeting of incredible global demand. Today, poppy is the most important medicinal or ornamental plant, as well as a source for seeds and seed oil (Bernath, 2006; Levy and Milo, 2006) and contributes greatly to the economy of Turkey. Turkey has a great place in world markets in both morphine and its derivatives exports as well as seed exports. In Turkey, 65,446,345 kg of morphine and its derivatives were exported in 2014 and 34,534,333,80 USD foreign exchange inflow was obtained. In addition, 2,452,47 kg of derivatives sale was made in Turkey, resulting in an income of 3,155,889,89 TL (Anon, 2014). 10% of the morphine and its derivatives produced in the Afyon Bolvadin Alkaloids Factory is used in local pharmaceutical industry and rest (90%) of it is exported for use in international pharmaceutical industry. USA is the biggest importer (85%) from Turkey; and the rest (15%) is imported by Asian, European and African countries. An average of US\$ 30 million foreign exchange is earned annually from morphine and its derivatives' exports from Turkey (Anon, 2013). Poppy is a multifaceted utilized however, alkaloids found in capsules are the main area of use in pharmaceutical industries. There must be a stable place in the world market for controlled legal alkaloid production to maintain quality of poppy products (Rezaei-Osalou, 2004). The high quality of the products that are obtained from the cultivated plants in a legal and controlled conditions is a subject that needs careful attention (Kapoor, 1995).

Poppy breeding is required for the development of new cultivars within existing gene pool of the species. Although poppy is self-pollinated crop, invariable percentage (15–40%) of foreign pollination is observed on *P. somniferum* depending on the cultivar and environmental factors (Morice and Louarn, 1971). Also *P. somniferum* heterosis determined for agronomic and chemical characters. Performance or hybrid vigor of a cross of two parental "inbred" lines in the first  $F_1$  hybrid generation and manifested increase in such characteristics (as size, growth rate, fertility) and positive increase in yield of a hybrid organism over those of its parents is called heterosis and has been recommended for genetic improvement in poppy (Lal and Sharma, 1991). Whereas, negative increase in yield components is called depression. All breeding activities are supported by conventional and molecular assisted selection. Although, opium poppy is a narcotic crop, due to the presence of morphine (narcotic constituent) in major proportion of opium latex; both positive and negative increase in morphine yield is of major economic importance globally.

At present, many scientists are working on improvement of poppy both to increase morphine contents and to produce food

**Table 1**

The seed color and major alkaloid types of *P. somniferum* cultivars and lines used in the study.

	Name of cultivar/line	Seed color	Alkaloids
Cultivars	Ofis-8	White	Morphine
	TMOT	Dark blue	Thebaine
Lines	TMO-A	White	Morphine
	TMO-B	gray	Thebaine
	N-207	Pink	Noscapine
	2010	White	Low morphine
	N-442	Dark Blue	Noscapine

grade morphine less cultivars using conventional and molecular approaches. To count a few, general and special combining abilities in diallel hybridization (Kaymak, 1980; Gümüştü, 2002; Dubey et al., 2007; Gümüştü and Arslan, 2008; Gümüştü et al., 2008; Shukla and Singh, 2006; Dogramaci, 2013; Anon, 2013; Valizadeh, 2015), determination of morphine contents (Marculescu and Bobit, 2001), alkaloid accumulation in capsules (Bernath et al., 2003), determination of chromosome numbers in wild poppy species (Rezaei-Osalou, 2004), correlation studies among agronomic characteristics like morphine latex yield, seed yield and other agronomic traits (Lachman et al., 2006), effects of water stress (Mahdavi-Damghani et al., 2010), have been reported by many workers for opium poppy improvement. The development of such varieties can assist opium cultivators to grow food grade poppy without any restriction or permission and also allow cultivation of morphine rich cultivars by specific farmers.

Therefore, the study aimed to determine effects of heterosis and heterobeltiosis from locally bred cultivars and lines and fixing the percentage of heterosis, to obtain high efficiency lines in terms of the seed and capsule yield and developing rich starting material in terms of total alkaloids and high or low morphine contents.

## 2. Material and methods

### 2.1. Seed material and procurement

*Papaver somniferum* L. cv. Ofis 8, TMOT, TMO-A and TMO-B were obtained from the General Directorate of Turkish Grain Board, (Toprak Mahsulları Ofisi—TMO), Ankara Turkey. Lines N-207, "2010" and N-442 were obtained from the poppy Seed Collection Section of the Department of Field Crops, Ankara University, Turkey. *P. somniferum* cultivars and lines used in this study were selected according to their morphological and agronomical features. The seed color and major alkaloid types of cultivars and lines used in the study are given in Table 1. Cv. Ofis-8, line TMO-A and line 2010 are white seeded genotypes. Cv. TMOT and line N-442 are dark blue colored seeded genotypes. Line TMO-B is a gray colored and line N-207 is pink colored seeded genotypes.

Whereas; Cv. Ofis-8 and line TMO-A are high morphine and line 2010 is low morphine genotype. Cv. TMOT and TMO-B are thebaine rich genotypes. Line N-207 and line N-442 are Noscapine rich genotypes.

These were selfed and their reciprocal crosses were made to obtain 42 hybrids for use in the experiment as shown in Table 3.

The poppy is a self-pollinated plant; where more often pollination occurs in unopened buds; therefore, care was taken during hand pollinating the flowers. The buds were covered with white-colored Mermerşahi Muslin Cloth<sup>®</sup> (Turkey); bags (with mesh size of 120/cm<sup>2</sup>) equipped with a draw string to facilitate a snug, gentle fit close to the stem base. Selected mother flowers of each genotype was emasculated in the bud before anther dehiscence in the morning and pollinated from donor to recipient using small paintbrushes. Paintbrushes were cleaned between each pollination by

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