EFFECT OF MAIN AND SECOND CROPPING ON SEED YIELD, OIL AND PROTEIN CONTENT OF SESAME (*Sesamum indicum* L.) GENOTYPES

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ABSTRACT

Double-cropping of sesame (*Sesamum indicum* L.) with small grains has been quite successful across the southeastern Turkey. However, producers in this region use planting dates ranging from early May as main crop (normal) through late June as second crop (late). We investigated the effect of the two sowing periods (early May and late June) on oil and protein content and seed yield of sesame genotypes under agro-climatic conditions of southern of Turkey in 2003 and 2004 growing seasons. Results indicated that sowing time significantly affected seed yield, 1000-seed weight, oil yield and protein yield. The highest seed yield was obtained when sesame genotypes were planted late (20 June) as second cropping. Genotype Y-A30 produced the highest seed yield (1352.2 kg ha^{-1}) across the 2-year study, averaging 430 and 422 kg ha^{-1} more seed yield than Vara Verde and Muganlı varieties, respectively. Results from the seed analyses indicated that no difference in oil and protein contents between sowing time was observed, while genotypes displayed significant variation amongst them for oil and protein contents. Furthermore, oil and protein yields appeared to change with sowing time and in general, the earlier sowing time decreased oil and protein yield as a result of higher pod yield.

INTRODUCTION

Sesame was an important crop in the Mesopotamian region during the third dynasty of Ur, 2130-2000 BC, which became the main centre of distribution of the species as a domesticated plant (Burkhill, 1953). Sesame is grown in a wide range of environments extending from the semi-arid tropics and sub-tropics to temperate regions. This has created a wide diversity of cultural system and genotype (Weiss, 2000). Farmers in southern of Turkey can take advantage of a long growing season by producing two crops per year. When used as a second crop, sesame is planted after the harvest of previous crops such as wheat, barley, chickpea or lentil. In this practice of double cropping, sowing times for the sesame crop are delayed until late June to early July. Seed yield is directly related to the number of branches, but the total number of capsules has the greatest direct effect on seed yield. The number of capsules per plant is directly related to the number of flowers, but climatic conditions can affect the percentage of fertilised flowers. High temperature (40 ^{0}C or above) at flowering will seriously affect fertilization and reduce the number of capsules. A short photoperiod can increase the number of capsules per plant on early and medium-late genotype. Seed oil content may vary considerably between genotype and seasons, and oil percentage tends to rise with increasing length of photoperiod. Highest oil content in Russia was in genotypes from Central Asia, Afghanistan and Turkey, and were claimed to reach 61-63% (Weiss, 2000). Yield reduction in late-planted determinate soybean has been attributed to reduced vegetative growth (Carter and Boerma, 1979). One possible method of increasing vegetative growth and yield in late planted soybean is to develop genotype with indeterminate growth habit (Boerma, 1979).

Early planting dates increased oil content in the Caucasus and Egypt; while location also has a substantial effect. Genotype grown at numerous sites in the USA showed a significant genotype-location interaction affecting seed composition. Average seed content was oil 53.4% and protein 26.3% (Li and Li, 1992). Other data indicate that genetic and environmental factors affecting protein content inversely affect oil content. Red and white seeds in Turkey had different oil contents, averaging 55% compared to 51%, and protein content of defatted seed was highest in red seeds at 44% (Kaya and Sarvan, 1996).

This research describes effects of the main (early) and second cropping (late) times on seed yield, oil and protein content of sesame.

MATERIALS AND METHODS

The field experiments were carried out in 2003 and 2004 at the experimental field of Agricultural Faculty, University of Dicle, Diyarbakir, Turkey to compare seed yield, capsule number, 1000-seed weight, oil and protein contents and their yields of early (5 May) and late (20 June) planted sesame varieties or genotypes. Vara Verde and Muganlı varieties introduced from Çukurova University, Agricultural Faculty, and the other eight sesame genotypes were collected from Diyarbakır province. All varieties and genotypes shown indeterminate growth type.

Diyarbakir province is located in South East Anatolian Region of Turkey. Soils are classified as clay. The region has a warm climate in summer, and the mean annual rainfall is around 450 mm, most of which fall in a major cropping season which extends from November to June. Thus, sesame can be grown during double cropping season with irrigation in cereal or food legume-based cropping systems in the region. Monthly rainfall, mean air temperature and humidity for 2003 and 2004 are presented in Table 1.

Table 1. Monthly temperature (^{0}C), rainfall (mm) and humidity (%) in the years 2003 and 2004.

Months	Temperature (^{0}C)		Rainfall (mm)		Humudity (%)	
	2003	2004	2003	2004	2003	2004
May	20.4	18.0	5.4	97.5	45.0	54.0
June	26.4	26.4	26.9	16.0	24.5	23.3
July	31.5	31.1	0.0	0.0	14.0	11.9
August	31.5	30.0	0.3	0.0	14.6	14.1
September	26.2	25.0	0.0	0.0	20.3	19.0
October	19.0	18.2	33.3	0.7	40.0	41.2

Source: Diyarbakir Meteorology Bulletin.

The treatments were replicated three times in split plot design with 2 sowing times (early May as main crop, and late June as second crop after wheat harvest) in the main plots and 10 genotypes in the sub-plots. The size of each plot was 2.8 x 5.0 m. Row spacing (four rows) was 0.7 m and the distance between plants in the row was 0.15 m, providing a sowing density of 9.5 plants m^2.The crop was fertilized with 70 kg N and 70

Table 2. Analysis of variance for seed yield, capsule number, 1000-seed weight, oil and protein contents and yields for sesame genotypes sown in early and late in 2003 and 2004.

Source of Variation	df[e]	Seed yield (kg ha^{-1})	Capsule (number plant^{-1})	1000-seed weight (g)	Seed oil (%)	Oil yield (kg ha^{-1})	Seed protein (%)	Protein yield (kg ha^{-1})
Year (Y)	1	**[a]	**	**	ns	**	ns	**
Sowing Time (S)	1	**	ns[d]	**	ns	*	ns	*
Y x S	1	**	ns	*	ns	*	ns	*
Genotype(G)	9	**	**	**	*	**	**	**
Y x G	9	**	**	**	ns	**	ns	**
S x G	9	**	**	*	ns	*	**	*
Y x S x G	9	*[b]	**	**	ns	*	ns	ns
% CV[c]		13.7	14.1	6.5	4.1	14.7	4.9	15.7

[a]significant at the 0.01 probability levels.
[b]significant at the 0.05 probability levels
[c]coefficient of variation
[d]non significant
[e]degrees of freedom

kg P_2O_5 ha^{-1} applied as basal dose in the form of 20-20-0 fertilizer prior to sowing. In addition, top dressing nitrogen was provided at the time of flowering at the rate of 70 kg ha^{-1} as ammonium nitrate (33% N) for all plots. Ten plants were selected randomly for recording number of capsule per plant before harvest. In both years, all plots were harvested at early September and late September for early and late sowing, respectively. After threshing, seed yield and 1000-seed weight were determined directly after correction for the seed moisture content (average 7%). In both years, the seeds from each plot were taken after harvest for determining oil and protein content of seeds. In order to determine the protein and oil contents, a 25 g sample of dry seeds from each plot were finely grounded. The each sample was analyzed for crude protein content with a model LECO FP-528 analyzer (LECO Corp., Joseph, MI), three reading for protein was taken from three sub-samples and their average value was recorded. The crude protein content in seeds was estimated by applying the factor N x 6.25 to the seed N content. Sesame flour was extracted into petroleum ether using soxhlet apparatus for 4h as per process of the instrument (AOAC, 1960). Oil contents were determined by weight differences. All values are mean of observations in three independent samples. Seed protein and oil contents were expressed in % on a dry matter basis. Oil and protein yields were calculated as a function of oil and protein contents and seed yield.

Data were subjected to analyses of variance for the combination of two years, sowing time, and genotype. Means of significant main effects were separated using LSD Test at P=0.05 (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The combined analyses of variance for seed yield, capsule number, 1000-seed weight, oil and protein contents and their yields are shown in Table 2. Year main effects strongly influenced seed yield, capsule number, 1000-seed weight, oil and protein yields. The main effects of sowing time were usually significant for seed yield, 1000-seed weight, oil and protein yields. All characters examined varied among the genotypes. In general, all interactions were significant for most of the tested characters exception of oil and protein contents (Table 3).

Effects of Years

Year main effects strongly influenced the seed yield, capsule number, 1000-seed weight, oil and protein yields (Table 2). Variations between years likely reflect differences in the environmental factors that influence sesame productivity. In this respect the considerable difference in temperature as well as sunshine hours between the years is noteworthy (Table 1).

Seed yield was higher in 2003, averaging 672 kg ha^{-1} more seed yield than in 2004. The differences between years for seed yield may be due to yearly environmental variation and the agronomic practices applied.

Differences occurred between years for capsule number per plant, and it was found to be higher in 2003 (91.8 no $plant^{-1}$) than in 2004 (68.0 no $plant^{-1}$). For 1000-seed weight, there were significant differences between years. In 2003, 1000-seed weight was higher than that of 2004 (4.08 and 3.62 g, respectively). Variation in oil and protein contents were not significant between 2003 and 2004; however, oil content was slightly higher in 2003 than 2004 (46.1 vs. 45.8%). Oil and protein yield varied between years, and the highest yield of oil and protein were recorded in 2003 (686.2 and 296.6 kg ha^{-1}, respectively) associated with seed yield (Table 3).

Effects of Sowing Time

Sowing time had a significant effect on seed yield, 1000-seed weight, oil and protein yields, but there were no significant effect on capsule number, seed oil and protein contents (Table 2). Compared to the May sowing, seed yield was higher by 16% in the June sowing. Thus, a late sowing time led to an increase of seed yield (from 1067.3 to 1240.5 kg ha^{-1}) (Table 3). The main reason for higher productivity of crop sown on June may be favorable temperature conditions during crop growth period. Kane et al. (1997) suggested that low vegetative-stage temperatures appeared to limit yield. Sesame encourages rapid germination, initial growth, and flower formation at a temperature around 30 ^{0}C (Weiss, 2000). Thus, in this study, optimal temperature occurred in late sowing time led to higher seed yield and yield attributes than earlier sowing time in May (Table 1 and Table 3).

Sowing on June (late) resulted in 0.5% higher 1000-seed weight over crop sown on May (early). This data suggest that seed development was affected by early sowing time led to reduction in the duration of seed filling as a result of slow growth at low temperatures.

Delaying planting from May to July had a large effect on oil and protein yields of all genotypes (Table 2). Averaged across genotypes, and years, the June planting yielded 14% and 13% higher than May planting for oil and protein, respectively (565.9 vs. 495.7 and 244.4 vs. 215.6 kg ha^{-1}, respectively). Kane et al. (1997) have reported early planting dates may not be feasible in some seasons or under some soil conditions (e.g., excess water, cool temperatures). Early planting resulted in the apparently unfavorable combination of cool vegetative-stage temperatures and warm seed-fill-stage temperatures.

As seen in Table 3, oil and protein contents were slightly higher in early sowing time (by 0.6 and 0.4%, respectively) than the late sowing time, but these variations were not significant for sowing time. Furthermore, capsule number per plant recorded higher in late sowing time than that of early sowing time (81.5 vs. 78.3 no plant^{-1}), although there were no significant differences between sowing times.

Effect of Genotype

As it seems in Table 2, all characters examined differed significantly among genotypes. Differences between genotypes were significant (P<0.01) for pod yield. According to the mean of two years, Y-A30 genotype had highest seed yield (1352.2 kg ha^{-1}) that was 430 kg and 422 kg ha^{-1} more than that of Vara Verde and Muganlı, respectively. Capsule number per plant obtained from Y-A30 genotypes which gave the highest seed yield, while Vara Verde and Muganlı had lowest capsule number (65.3 and 64.9, respectively).
Differences in seed yield and capsule number observed across genotypes were associated with the genetic differences among genotypes. 1000-seed weight also varied among genotypes. The highest value obtained for Y-C12, Y-13 and Y-A30 genotypes (4.23, 4.04 and 4.03 g, respectively). The other genotypes had similar seed weight ranged from 3.44- 3.94 g.

The oil and protein content for genotypes are presented in Table 2. Significant differences were observed among genotypes for oil and protein content.

Table 3. The effects of year and sowing time on seed yield, capsule number, 1000-seed weight, oil and protein content and yields of sesame genotypes.

Treatments	Seed yield (kg ha^{-1})	Capsule number plant^{-1}	1000-seed weight (g)	Seed oil (%)	Oil yield (kg ha^{-1})	Seed protein (%)	Protein yield (kg ha^{-1})
Year							
2003	1490.1±44.4	91.8±2.6	4.08±0.05	46.15±0.27	686.2±19.9	19.86±0.19	296.6±9.5
2004	817.6±18.3	68.0±1.4	3.62±0.04	45.88±0.27	375.4±9.0	19.94±0.19	163.4±4.2
LSD	56.3	3.9	0.07	--	27.8	–	12.9
Sowing Time							
Early	1067.3±45.7	78.3±2.8	3.75±0.04	46.31±0.26	495.7±21.8	20.10±0.21	215.6±10.0
Late	1240.5±61.7	81.5±2.4	3.95±0.06	45.72±0.28	565.9±27.9	19.70±0.16	244.4±12.3
LSD	56.3	–	0.07	–	27.8	–	12.9
Genotype							
Vara Verde	922.0±72.2	65.3±3.5	3.65±0.08	44.56±1.03	409.4±32.1	17.92±0.30	165.5±13.4
Muganlı	929.5±63.9	64.9±2.8	3.92±0.10	46.37±0.51	428.7±26.9	20.80±0.32	194.5±14.9
Y-13	1125.3±138.7	79.3±7.0	4.04±0.08	44.87±0.66	503.2±60.3	19.54±0.32	217.6±25.0
Y-2	1142.1±100.4	77.6±3.0	3.44±0.08	46.45±0.52	530.6±46.0	18.45±0.25	212.2±20.7
Y-7	1244.8±144.6	84.5±6.1	3.66±0.24	46.11±0.60	572.4±65.1	21.24±0.36	264.3±30.3
Y-A24	1244.9±115.6	83.8±3.8	3.78±0.10	46.21±0.33	575.2±52.8	19.14±0.37	237.6±21.6
Y-A3	1230.1±104.4	87.5±4.6	3.94±0.06	46.85±0.45	575.7±47.8	20.05±0.43	246.3±21.5
Y-C6	1074.4±119.4	76.7±7.2	3.84±0.07	47.24±0.43	511.0±59.2	19.94±0.23	213.8±23.6
Y-C12	1273.7±154.1	87.8±6.7	4.23±0.12	46.27±0.49	590.1±71.1	21.27±0.22	271.3±32.6
Y-A30	1352.2±161.1	91.4±7.1	4.03±0.08	45.21±0.60	611.8±74.2	20.65±0.28	276.9±31.1
LSD	126.0	8.9	0.19	1.58	62.3	0.83	28.9
Mean	1153.9±39.0	79.9±1.8	3.85±0.04	46.01±0.19	530.8±17.9	19.90±0.13	230.0±08.0

±, standard error of mean

Oil content was highest for Y-C6 genotype (47.2%), and ranged from 45 to 46 mg g^{-1} for most of genotypes. Inheritance studies on oil content in sesame have revealed a strong genetic control of the trait (Das and Samanta, 1998). Furthermore, genotypic differences for oil content have been reported with oil content displaying more genetic variability among cultivars than the other oil traits (Ashri, 1999; Baydar et al., (1999). The highest protein content obtained from Y-7 and Y-C12 (21.2%), while Vara Verde had the lowest protein contents (17.9%).

Effect of interactions

As it seems in Table 2, seed yield, 1000-seed weight, oil and protein yield were affected significantly by year x sowing time interaction. Thus, the highest seed yield was obtained from late sowing in 2003 (1646.9 kg ha^{-1}). In the second trial year, seed yield showed the lowest value when crop sown in early May (801.1 kg ha^{-1}). In 2003 cropping season, the genotypes sown in late-June gave the highest 1000-seed weight (4.2 g). The highest oil and protein yields were achieved with the late sowing time in 2003 trial year (745.5 and 324.4 kg ha^{-1}, respectively) (data not shown in Table).

Year x genotype interaction were significant ($P<0.01$) for most of the tested characteristics exception of oil and protein content. In the first trial year, the highest seed yield was obtained from Y-A30 genotype (1865.3 kg ha^{-1}), while in the second year of the experiment, the highest seed yield was obtained from Y-A24 and Y-A3 genotypes (953.1 and 937.4 kg ha^{-1}, respectively) as a result of their high capsule number per plant. Capsule number per plant was also affected by year x genotype interaction. Y-A30 genotype gave maximum capsule number (110.2 no $plant^{-1}$) in 2003, and Y-A24 and Y-A3 genotypes which had the highest seed yields have the highest capsule number in 2004 (81.6 and 78.8 no $plant^{-1}$, respectively). The highest 1000 seed weight obtained from Y-C12 and Y-A30 genotypes in 2003 trial year (4.5 and 4.2 g, respectively), while Y-13, Y-A3, Y-C12 and Y-A30 have similar 1000 seed weight in 2004 (3.8 g). Oil and protein yields were highest for Y-A30 in the first year (843.3 and 375.7 kg ha^{-1}, respectively), while it was highest for Y-A3 in the second year (439.9 and 192.5 kg ha^{-1}, respectively) (data not shown in Table).

Significant differences *(*$P<0.01$*)* for sowing time x genotype interaction were observed for all variables examined except for oil content (Table 2). Genotype Y-A24 sown in May had a maximum seed yield (1443.6 kg ha^{-1}). This difference may result from differences in climatic conditions. This may also be accounted for by a genotype effect. Y-A30 gave also the highest capsule number in late sowing time (100 capsule $plant^{-1}$). While, in late sowing, Y13 gave the highest capsule number together with Y-A24 genotype (93 capsule $plant^{-1}$). These resulted in a significant sowing time by genotype interaction (Table 2). Furthermore, Y-C12 genotype gave higher 1000-seed weight (4.2 g) at early sowing time. This genotype gave also the highest 1000-seed weight together with Y-13 genotype (4.1 g) when they planted late. No interaction between genotype and sowing time was identified for oil content, but genotype by sowing time interaction ($P<0.01$) was observed for protein content. Y-7 genotype gave higher protein content (22.1%) than the other genotypes at early sowing time, whereas Y-C12 and Y-A30 genotypes gave higher protein content (20.8%) than the other genotypes at late sowing time. Genotype x sowing time interactions were also significant for oil and protein yields. Mean oil and protein yields of genotypes increased by 661 kg ha^{-1} for oil yield and 281.4 kg ha^{-1} for protein content in late sowing time (data not shown in Table).

A significant Y x S x G interactions were significant for seed yield, capsule number per plant and 1000-seed weight as well as for oil yield (Table 2). In 2003, Y-C12 had the highest seed yield when it planted late (1945.2 kg ha^{-1}), while in 2004, Y-A24 which sown late gave the highest seed yield (1039.9 kg ha^{-1}). Y x S x G effects on capsule number was significant at the $P=0.01$ level (Table 2). In 2003, capsule number of the genotypes ranged from 64 to 125 no $plant^{-1}$, and in the early sowing, Y-A30 genotype had the highest capsule number. In late sowing, Y-A24 genotype gave the highest capsule number of 86 no $plant^{-1}$. In the first trial year, seed obtained from Y-7 and Y-C12 genotypes planted late had the highest1000 seed weight (4.9 and 4.5 g, respectively). Furthermore, Y-C12 planted in early gave also the highest seed weight (4.6 g). In 2003, the highest oil yield was obtained from Y-A12 (891.0 kg ha^{-1}), when sown late, while Y-A24 gave oil yield in the late sowing in 2004 (480.6 kg ha^{-1}) (data not shown in Table).

The results showed that protein content is inversely related to oil content (Weiss, 2000; Whigham and Minor, 1978). Oil yields of the genotypes ranged from 611.8 to 409.4 kg ha^{-1}, and Y-A30 had the highest oil yield as result of the highest seed yield. Furthermore, protein yields ranged from 276.9 to 165.5 kg ha^{-1}, and the highest protein yield was also obtained from Y-A30 (276.9 kg ha^{-1}) which had the highest pod yield.

CONCLUSION

An important findings of the study was the increase of seed yield and yield attributes with late sowing (June) of indeterminate sesame genotypes after wheat or legume crops harvest under southeastern Turkey conditions. This result suggests that farmers should sow sesame when temperature reached to approximately 30 ^{0}C for maximum yield. Thus, double-cropping (late sowing) is an important production system for sesame in the region. Furthermore, it is concluded that indeterminate sesame genotypes to be well adapted to late-planting in the Southeastern Anatolian Region of Turkey.

ACKNOWLEDGEMENTS

The author thank Dicle University Scientific Research Project Coordinatory for its funding of this research.

LITERATURE CITED

Ashri, A. 1999. Sesame. In: Röbbelen, G., Downey, R.K., Ashri, A. (Eds), Oil Crops of the World: Their Breeding and Utilization, McGraw-Hill, NY, 375–387.

AOAC. 1960. Official Methods of Analysis. Association of Official Agricultural Chemistry, Washington, DC.

Baydar, H., I. Turgut, K. Turgut. 1999. Variation of certain characters and line selection for yield, oil, oleic and linoleic acids in the Turkish sesame (*Sesamum indicum* L.) populations, Turkish Journal of Agriculture and Forestry, 23: 431–441.

Boerma, H.R. 1979. Breeding soybean for double-cropping. In: Loden, H.D., Wilkenson, D. (Eds.) Proc. 8th Soybean Seed Res. Conf., Chicago, IL. 14-15 Dec. 1978. American Seed Trade Assoc., Washington, DC.

Burkhill, I.H., 1953. Habits of man and the origins of the cultivated plants of the Old World. Proc. Linn. Soc. Lond. 164: 12–42.

Carter, T.E. and H.R. Boerma. 1979. Implications of genotype x planting date and row spacing interactions in double-cropped soybean genotype development. Crop Science, 19: 607–610.

Das, A. and S.K. Samanta. 1998. Genetic analysis of oil content and fatty acids in sesame (*Sesamum indicum* L.), Crop Research, 15: 199–205.

Kaya, N. and A.F. Savran 1996. Biochemical studies on seeds of sesame (*Sesamum indicum* L.) genotypes. Ege Üniversitesi Ziraat Fakültesi Dergisi, 33 (2/3): 33-40.

Li, C. and Y. Li. 1992. Study of sesame seed development. Sesame Safflower Newsletter, 7: 8-17.

Kane, M.V., C.C. Steele and L.J. Grabau. 1997. Early-maturing soybean cropping system: I. Yield responses to planting date. Agronomy Journal, 89: 454–458.

Steel, R.G.D. and Torrie, J.H. 1980. Principles and Procedures of Statistics. 2nd Edition Mc Graw Hill Book Comp., New York.

Weiss, E.A., 2000. Oilseed Crops. Second Edition, Blackwell Science, Oxford.

Whigham, D.K. and H.C. Minor. 1978. Agronomic characteristics and environmental stress. Norman, A.G.(Ed). Soybean Physiology, Agronomy and Utilization 249 p. Academic Press, London.