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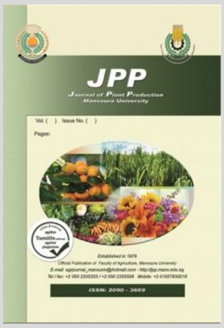
# Combining Ability and Heterosis for Fodder Yield and Other Associated Traits in Oat (*Avena sativa* L.)

**Al-Juhaishi, M. O. H.*; A. M. A. Okaz; M. A. El-Hennawy and E. I. Zaazaa**

Agronomy Dept., Fac. of Agric., Al-Azhar Univ. Cairo, Egypt.




## ABSTRACT

Combining ability and heterosis studies were performed on half diallel mating. The basic material for the present study consisted of six diverse genotypes of oats viz: Alguda, Anatolia, Kangaroo, ICARDA tall, Bihuth and Shifa'.15 $F_1$ hybrids and their parents were grown in randomized complete block design with three replications. Observations were recorded on six quantitative traits. The analysis of variance revealed significant differences among the parents and their crosses for all the studied traits. The estimates of variance due to non-additive gene action ($\sigma^2$D) was much higher than the corresponding additive genetic variance ($\sigma^2$A) for all the traits under evaluation.Values of GCA effects revealed that ICARDA tall was found to be the best general combiner for biological yield amongst all the parents. It was also found to have significant positive GCA values for other traits. On the basis of significant SCA effects, hybrids ICARDA tall x Bihuth and Alguda x Bihuth recorded highest SCA effects for biological yield, also showed positive and significant SCA values for other traits. The $F_1$ hybrids were showed the best specific combinations viz; Bihuth x shifa' for days to 50% heading and days to 75% maturity, Anatolia x Kangaroo for plant height at maturity,Anatolia x Bihuth for numbers of tillers. Highest significant and positive heterosis for biological yield was shown by $F_1$ hybrid Alguda x Bihuth followed by ICARDA tall x Bihuth. These crosses combinations also exhibited highly values with positive and significant heterobeltiosis for two traits viz; plant height at maturity and growth rate.

***Keywords:*** Avena sativa; Oat; Heterosis; GCA; SCA; Fodder yield

## INTRODUCTION

Oat (*Avena sativa* L., 2n= 6x = 42) belongs to the poaceae family and ranks sixth in the world's cereal production statistics after wheat, maize, rice, barley and sorghum (FAO, 2018). In Egypt, the total area covered under oats cultivation is dedicated to forage production. According to official statistics, the volume of imports of oats reached more than 1000 tonnes (Central Agency for Public Mobilization and Statistics, 2018). Oats are one of the most important winter forage and grain crops cultivated worldwide for animal and human consuming. It is a fast-growing, dulcet, succulent and nutritious fodder crop. The oat fodder is gaining significance and the oat crop is catching up in a supplement the high dry matter content and quality in mixture with berseem and Lucerne fodder.

World oat production is generally concentrated between Latitudes 36-65º N and 20-46º S. Oat is an annual cool season grass crop adapted mainly to the moist areas of the temperate climates of the world (Harlan and dw Wett, 1971). For human food oat groat is desired, that high in protein, β-glucan and low in oil, whereas high oil and low β-glucan with the high protein is desired for livestock feed to maximize the energy (Peterson *et al.*, 2005).

Plant breeders are continuously searching for germplasm which might be useful in attaining the objectives of their breeding programs. Plant breeders usually develop populations for cultivar development from crosses within regionally adapted germplasm with good agronomic performance. Exchange of lines and cultivars between breeders is common but occurs mainly within certain regions. Exchange of breeding lines across continents is less common (Buerstmayr *et al.*, 2007).

On the other hand, landraces are a good source for expanding genetic variations which allow the development of new cultivars with high quality traits. Oat breeding programs depend on selecting good parents to develop new varieties that carry genetic factors that improve grain yield and some other beneficial traits. (Ribeiro *et al.*, 2011).

Diallele analysis is the most popular way and has been extensively used in both self and cross pollinated crops. The diallel cross designs are frequently used in plant breeding research to obtain information about genetic properties of parental lines or estimates of general combining ability (GCA), specific combining ability (SCA) and heritability reported by (Iqbal *et al.*, 2007).

Combining ability analysis helps identify parents with high GCA effects and their combinations with high SCA effects. Based on combining ability analysis of various traits, higher SCA effects indicate to dominance gene effects and higher GCA effects point a greater role for the effects of additive genes controlling traits. If both the GCA and SCA effects are not considerable, epistatic gene effects may play an important role in the inheritance of traits (Sprague and Tatum, 1942).

The heterosis responses in oat are not well defined. The diffculty of crossbreeding and producing large numbers of $F_1$ seeds prompted most researchers to compare the performance of the $F_1$ hybrid and their parents

* **Corresponding author.**
**E-mail address: moh91omer@gmail.com**
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in space-grown populations. (Murphy, 1966). Heterobeltiosis, the increase or decrease of $F_1$ value over better parent, is usually expressed as economic heterosis, but from practical point of view, standard heterosis, which represents the increase of $F_1$ value over the best standard cultivar, is more appropriate (Prakash *et al.,* 2013).

The objective of this study were: i) estimate combining ability effects for some parameters in oats and nature of gene action, and ii) estimate the heterotic response mid-parent parent and over better for biological yield and its components.

## MATERIALS AND METHODS

**Plant materials**

The experiment included six oat cultivars were sourced from different countries (Table, 1). The 6 entries were sown in a newly reclaimed land for two years 2018/2019 and 2019/2020 at the Experimental Farm of Agronomy Department, Faculty of Agriculture, Al-Azhar University, Cairo, Eygpt. The six genotypes of oat (*Avena sativa* L.) viz: Alguda, Anatolia, Kangaroo, ICARDA Tall, Bihuth and Shifa', were selected from the germplasm collection (four origins) were obtained from a large number of breeders.

**Table 1. Some information of the oat genotypes used in the study.**

| Genotype No. | code | Genotype Name | source | Genotype No. | code | Genotype name | source |
|---|---|---|---|---|---|---|---|
| 1 | V1 | Alguda | Italian | 4 | V4 | Kangaroo | Australian |
| 2 | V2 | Anatolia | Italian | 5 | V5 | Bihuth[b] | Iraqi |
| 3 | V3 | ICARDA tall | ICARDA[a] | 6 | V6 | Shifa'[c] | Iraqi |

**[a] (International Center for Agricultural Research in the Dry Areas), [b] (11بحوث) and [c] (شفاء)**

**Field trials**

The field experiments were carried out in a randomized complete block design (RCBD) with three replications. The selected genotypes were crossed in 6 x 6 half diallel mating design [n(n-1)/2] to obtain 15 $F_1$ hybrids, during 2018/19. The trial comprising of 15 $F_1$s and their parents was conducted during the winter season of 2019/20 to evaluated $F_1$s crosses and their parents. The experimental plot comprised of one row each of 2 m length. Plant spacing was maintained at 30 cm x 10 cm.

Observations were recorded on ten randomly selected plants from each genotype in all the three replications. Recommended package of agricultural practices to raise a good crop was followed. There was no application of chemicals to control pests, diseases and weed. However, there was just application of mechanical methods to control weeds.

**Investigated traits**

Observations were recorded on six quantitative traits viz. days to 50% heading, days to 75% maturity, plant height at maturity (cm), number of tillers per plant, biological yield (g/plant) and plant growth rate (g/day/plant). The harvested plants were dried at 40–42ºC for 24h to achieve a uniform moisture content of all samples.

**Statistical analysis**

Data were underwent to an analysis of variance to find significant variations between genotypes for the limited data. After obtaining the significant variations, the data recorded on parents and their $F_1$s were underwent to combining ability analysis following (Griffing, 1956) method-II and model-I (fixed model).

The percentage increase or decrease in the $F_1$ hybrids over better parent and mid-parent was calculated to evaluation the potential heterotic effects of the above parameters (Turner, 1953).

## RESULTS AND DISCUSSION

The analysis of variance (Table, 2) revealed significant differences with respect to different characters among genotypes for days to 50% heading, days to 75% maturity, plant height at maturity, numbers of tillers per plant, biological yield per plant and growth rate.

Significant variations were found between the parents and their hybrids for all the studied characters, pointing to the materials selected were various and also resulted in the creation of great genetic diversity in the hybrids. The variance of parents vs crosses was very significant for all the studied characters, indicating the potential of heterotic effects in improving fodder quality and yield. These results are in general accordance with those obtained by Kumar *et al.,* (2017).

**Table 2. Analysis of variance of the different studied characters for parents and hybrids of oat during 2019/20 season.**

| Source of variation | d.f. | Days to 50% heading | Days to 75% maturity | Plant height (cm) | No. of tillers /plant | Biological yield (g/plant) | Growth rate (g/day/ plant) |
|---|---|---|---|---|---|---|---|
| Replication | 2 | 1.973 | 8.932 | 31.68 | 1.722 | 9.03 | 0.0009 |
| Genotypes | 20 | 209.0** | 155.1** | 398.9** | 25.46** | 2480.8** | 0.104** |
| Parent | 5 | 229.3** | 321.2** | 481.8** | 13.72** | 398.47** | 0.008** |
| Crosses | 14 | 202.1** | 94.90** | 312.1** | 7.541** | 2394.7** | 0.106** |
| Parents vs Crosses | 1 | 204.5** | 167.6** | 1200.0** | 335.0** | 14098.7** | 0.550** |
| Error | 40 | 1.357 | 0.820 | 1.621 | 0.646 | 20.256 | 0.001 |

***, ** Significant at $P < 0.05$ and $P < 0.01$**

The analysis of variance for combining ability for different characters was presented in (Table, 3). Analysis revealed significant GCA and SCA mean squares for all the studied traits. The estimates of variance due to non-additive gene action ($\sigma^2$D) was much higher than the corresponding additive genetic variance ($\sigma^2$A) for all the traits under estimate, the differences due to SCA effects were higher than those for GCA effects. Therefore, these characters can be exploited via heterosis breeding to enhance the forage yield in oat. Fodder yeild traits showed superiority of over dominance, pointing to the present group of materials was various and contained different alleles which upon combination through crossbreeding increased heterozygosity and could drive to hybrid vigour.

Furthermore, the GCA variation of parents and SCA variation of the crosses play an important role in parents' selection in breeding program. In this paper, the effects of the ability to combine 6 cultivars were evaluated for their genetic value for use in the production of superior strains.

**Table 3. Analysis of variance for GCA and SCA for the different studied characters of oat genotypes during 2019/20 season.**

| Source of variation | d.f. | Days to 50% heading | Days to 75% maturity | Plant height (cm) | No. of tillers /plant | Biological yield (g/plant) | Growth rate (g/day/ plant) |
|---|---|---|---|---|---|---|---|
| GCA | 5 | 129.4** | 112.8** | 301.5** | 8.595** | 830.3** | 0.038** |
| SCA | 15 | 49.75** | 31.34** | 76.80** | 8.45** | 825.8** | 0.033** |
| Error | 40 | 0.452 | 0.273 | 0.540 | 0.215 | 6.752 | 0.000 |
| GCA/SCA | | 0.327 | 0.453 | 0.493 | 0.127 | 0.126 | 0.141 |
| $\sigma^2$A | | 19.9 | 20.3 | 56.1 | 0.036 | 1.131 | 0.001 |
| $\sigma^2$D | | 49.2 | 31.0 | 76.2 | 8.234 | 819.0 | 0.033 |

***, ** Significant at P < 0.05 and P < 0.01**

Additional review of the data on the parents' GCA effects (Table, 4) showed that all of the parents participating in the study were a good general combiner for most of the traits under study. ICARDA tall was found to be the best general combiner for biological yield per plant amongst all the parents. It was also found to have significant positive GCA effects for three traits viz; days to 75% maturity, plant height at maturity and growth rate.

Besides ICARDA tall, only two parents Bihuth and Alguda showed positive and significant GCA effects for biological yield and rest all of the parents exhibited significant and negative GCA effects for this trait. For other important traits contributing towards biological yield like days to 50% heading only two parents Shifa' and Anatolia had significant and positive GCA effects. Genotypes Shifa' and ICARDA tall showed high values of significant and positive GCA effects for days to 75% maturity. For plant height two genotypes Anatolia and ICARDA tall and Alguda were the best general combiners parents for this trait. For numbers of tillers per plant three parents viz; Kangaroo, Shifa' and Bihuth showed significant and positive values of GCA effects. Alguda, ICARDA tall and Bihuth were the best general combiners for growth rate, respectively. While, rest all parents showed significant and negative values of GCA for this traits. Parents ICARDA tall and Bihuth with important GCA effects for most characters can be used on a large scale in hybridisation program to accelerate the genetic improvement of quality and forage yield. These genotypes could serve as a source for isolating desired new lines. Parents who present higher GCA effects should be preferred to be part of the crossbreeding program, to select promising homozygous strains (Ahmad et al., 2013). The estimates of the effects of GCA listed in (Table, 4) appeared a difference between one individual parent and the other and from one trait to the next.

**Table 4. Estimates of general combining ability effects of parents for the various studied characters of oat during 2019/20 season.**

| Source of variation | d.f. | Days to 50% heading | Days to 75% maturity | Plant height (cm) | No. of tillers /plant | Biological yield (g/plant) | Growth rate (g/day/ plant) |
|---|---|---|---|---|---|---|---|
| Alguda | V1 | -1.275** | -4.832** | 1.342** | -1.651** | 4.85** | 0.060** |
| Anatolia | V2 | 1.250** | -1.628** | 8.829** | -0.714** | -4.31** | -0.020* |
| ICARDA tall | V3 | 0.146 | 3.151** | 3.579** | 0.149 | 11.039** | 0.058** |
| Kangaroo | V4 | -5.846** | -1.149** | -8.554** | 1.224** | -17.72** | -0.115** |
| Bihuth | V5 | -0.821** | -1.186** | -0.454 | 0.249* | 6.401** | 0.048* |
| Shifa' | V6 | 6.546** | 5.643** | -4.742** | 0.744** | -0.257 | -0.031* |
| SE (gi) | | 0.217 | 0.169 | 0.237 | 0.150 | 0.839 | 0.006 |
| SE(gi-gj) | | 0.336 | 0.261 | 0.368 | 0.232 | 1.299 | 0.009 |

***, ** Significant at P < 0.05 and P < 0.01**

The effects of SCA of hybrids on the biological yield and characters of other components are shown in (Table, 5). A review of the data showed that, of the fifteen hybrids that were generated and evaluated, eight hybrids had highly significant and positive SCA effects.Hybrid V3 x V5 recorded highest SCA effects for biological yield and growth rate closely followed by V1 x V5 and V1 x V4.

Also, showed positive and significant SCA effects for all the traits. Further, perusal of the data exhibited that the best specific combinations were the $F_1$ hybrids viz; V5 x V6 for days to 50% heading and days to 75% maturity, V2 x V4 for plant height at maturity, V2 x V5 for number of tillers. Some of these hybrids correlated with their parents' GCA effects and found that at least one parent had high or moderate GCA effects for the specific traits. Similar results were also obtained by Hathcock and McDaniel (1973), Stuthman and Stucker (1975), Pixley *et al.*, (1981) and Kapoor and Singh (2017). These combinations may give rise to transgressive segregants.

Anyway, some of the best specific combinations were gained from parents who have low and even negative effects for GCA, which means that some of the most desirable effects of SCA can be managed by low GCA parents.

**Table 5. Estimates of specific combining ability effects of crosses for the different studied characters of oat during 2019/20 season.**

| Source of variation | Days to 50% heading | Days to 75% maturity | Plant height (cm) | No. of tillers /plant | Biological yield (g/plant) | Growth rate (g/day/ plant) |
|---|---|---|---|---|---|---|
| V1 × V2 | -3.732** | -5.791** | -3.566** | -0.303 | -15.27** | -0.071** |
| V1 × V3 | -2.095** | 1.496** | 1.851** | 1.335** | 5.88* | 0.033* |
| V1 × V4 | 4.064** | 6.296** | 6.784** | 1.926** | 27.97** | 0.156** |
| V1 × V5 | 0.939 | 2.901** | 11.12** | 2.068** | 32.28** | 0.213** |
| V1 × V6 | -6.828** | -1.729** | 1.171 | 2.172** | 22.67** | 0.163** |
| V2 × V3 | -7.686** | -5.308** | -4.204** | 0.497 | 0.47 | 0.036* |
| V2 × V4 | -2.261** | 0.459 | 15.76** | 2.855** | 16.03** | 0.108** |
| V2 × V5 | 0.447 | 3.263** | -4.870** | 3.064** | 19.54** | 0.117** |
| V2 × V6 | 7.747** | 5.034** | 12.85** | 1.968** | 12.33** | 0.052** |
| V3 × V4 | -2.024** | 2.346** | 7.046** | 0.793 | 5.34* | 0.025 |
| V3 × V5 | 1.518* | 2.251** | 9.113** | 2.201** | 50.86** | 0.322** |
| V3 × V6 | -10.88** | -6.745** | -3.299** | 0.972* | -11.118** | -0.040* |
| V4 × V5 | -5.157** | 5.884** | -6.387** | -0.007 | -40.49** | -0.295** |
| V4 × V6 | -4.490** | -2.145** | -3.566** | 1.797** | -2.46 | -0.004 |
| V5 × V6 | 13.35** | 7.259** | 1.601* | 0.539 | 17.89** | 0.072** |
| SE (Sij) | 0.596 | 0.464 | 0.652 | 0.411 | 2.303 | 0.016 |
| SE(Si-Sik) | 0.890 | 0.692 | 0.972 | 0.614 | 3.437 | 0.024 |

***, ** Significant at P < 0.05 and P < 0.01**

**Heterosis expression:** The estimation of heterosis would be useful to judge the best hybrid combinations for exploitation of superior hybrids. Heterobeltiosis and heterosis values of 15 $F_1$ crosses for biological yield and related traits showed that the majority of the $F_1$ crosses created higher values compared to parental genotypes (Table, 6). Highest significant and positive heterosis for biological yield (71.87%) was shown by $F_1$ hybrid V1 x V5 over better parent followed by V3 x V5 (76.21%) over mid-parent. These crosses combinations also exhibited highly values with positive and significant heterobeltiosis for two traits viz; plant height at maturity (12.75%) and growth rate (64.4%), respectively. The results showed that, out of the fifteen hybrids evaluated, fourteen $F_1$ hybrids revealed positive and significant heterosis for biological yield with heterosis values ranged from 9.35% to 76.21% over mid-parent. Highly significant positive estimates of heterosis for days to 50% heading was found in cross V5 x V6 with (4.73%) over better parent and (15.18%) over mid-parent. $F_1$ V4 x V5 showed highly significant estimates of heterosis for days to 75% maturity with (8.84%) over better parent and (10.61%) over mid-parents. In the present investigation the cross V2 x V5 indicated significant positive heterosis over better parent and over mid-parent (88.2%) and (121.2%), respectively, for number of tillers per plant. These promising crosses were selected on the basis of geographical difference and their SCA effects with respect to biological yield and its components. Interestingly, to note that the majority of hybrids showing heterobeltiosis and heterosis and SCA effects for some traits were also amongst the best performing for the same characters; Therefore, using heterosis to improve these traits may be beneficial.

**Table 6. Estimates of heterosis (%) over better parent (BP) and mid-parent (MP) of crosses for the different studied characters of oat during 2019/20 season.**

| Source of variation | Days to 50% heading | | Days to 75% maturity | | Plant height (cm) | | No. of tillers /plant | | Biological yield (g/plant) | | Growth rate (g/day/ plant) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BP | MP | BP | MP | BP | MP | BP | MP | BP | MP | BP | MP |
| V1 × V2 | -8.46** | -6.72** | -6.99** | -3.96** | -1.96 | 3.2** | 58.33** | 86.12** | 10.42** | 11.48** | 13.44** | 16.04** |
| V1 × V3 | -12.5** | -8.67** | -6.04** | 0.55 | 3.27** | 6.08** | 31.74** | 83.08** | 20.88** | 33.76** | 28.64** | 33.39** |
| V1 × V4 | -4.23** | -0.32 | 6.51** | 7.49** | 3.94** | 12.27** | 30.26** | 89.78** | 42.93** | 51.87** | 31.77** | 41.19** |
| V1 × V5 | -2.38* | 1.83* | 5.97** | 6.71** | 12.75** | 12.83** | 60.0** | 114.3** | 71.87** | 72.02** | 60.21** | 61.21** |
| V1 × V6 | -13.2** | -8.30** | -7.20** | -0.35 | 2.67* | 5.61** | 43.57** | 102.3** | 45.12** | 50.04** | 44.39** | 50.14** |
| V2 × V3 | -15.3** | -13.14** | -8.34** | -4.89** | -0.94 | 1.58 | 33.04** | 63.64** | 8.90* | 19.48** | 18.78** | 25.88** |
| V2 × V4 | -11.3** | -6.08** | -0.16 | 2.17** | 4.06** | 17.81** | 50.92** | 97.11** | 19.14** | 27.73** | 19.32** | 25.14** |
| V2 × V5 | -4.1** | 1.85* | 1.74* | 5.77** | -3.93** | 1.19 | 88.29** | 121.2** | 46.74** | 48.27** | 36.06** | 40.02** |
| V2 × V6 | 1.66 | 5.52** | -0.89 | 3.21** | 4.63** | 13.12** | 52.70** | 91.17** | 26.57** | 29.65** | 23.42** | 25.52** |
| V3 × V4 | -16.6** | -9.48** | -3.15** | 2.75** | 0.11 | 10.83** | 37.64** | 48.9** | 1.89 | 19.01** | 5.18** | 16.56** |
| V3 × V5 | -8.96** | -0.97 | -3.23** | 4.23** | 6.93** | 9.92** | 67.83** | 77.47** | 59.12** | 76.21** | 64.4** | 69.45** |
| V3 × V6 | -15.5** | -14.50** | -5.32** | -4.97** | -4.27** | 1.07 | 51.04** | 54.56** | 2.71 | 10.2** | 7.66** | 15.91** |
| V4 × V5 | -5.37** | -5.15** | 8.84** | 10.61** | -6.53** | 0.89 | 29.89** | 47.9** | -25.0** | -20.4** | -33.34** | -28.1** |
| V4 × V6 | -15.1** | -6.92** | -5.13** | 1.00 | -2.25* | 2.79** | 55.35** | 64.45** | -0.25 | 9.35** | 5.12** | 8.47** |
| V5 × V6 | 4.73** | 15.18** | 0.80 | 8.94** | 1.84 | 4.69** | 46.89** | 58.74** | 42.04** | 46.98** | 28.51** | 34.42** |
| SE(+) | 0.951 | 0.824 | 0.740 | 0.640 | 1.040 | 0.900 | 0.656 | 0.568 | 3.675 | 3.182 | 0.026 | 0.022 |

***, ** Significant at P < 0.05 and P < 0.01**

Results (Table 7) showed that the PCV values were higher than the GCV values for all the studied traits. The difference between the phenotypic and genetic coefficient of variation was rather low, which indicates that the genetic variation mainly contributes to the phenotypic variation of these traits. The strength of the hybrid achieved high significant and desirable values in most of the traits, as there was an over-dominance and control of the non-additive genetic action over the inheritance of these traits, the degree of dominance represented by the over-dominance for all the studied traits. The degree of heritability in the narrow concept showed low values in most traits, which indicates the importance of the non-additive gene action. Forage yields of oat can be improved through the application of effective selection in the late segregation generations for all the studied traits and for all the studied hybrids, as transgressive segregants were identified desirable.

**Table 7. Genetic parameters of variation for biological yield and its components in oat during 2019/20 season.**

| Traits | Mean | Degree of dominance | Coefficient of variation % | | Heritability % | |
|---|---|---|---|---|---|---|
| | | | Genotypic | Phenotypic | Broad sense | Narrow sense |
| Days to 50% heading | 101.16 | 1.5 | 3.1 | 6.9 | 99.35 | 28.60 |
| Days to 75% maturity | 147.48 | 1.2 | 2.1 | 3.7 | 99.47 | 39.39 |
| Plant Height (cm) | 147.13 | 1.1 | 3.6 | 5.9 | 99.59 | 42.24 |
| No. of tillers per plant | 10.26 | 15.0 | 1.3 | 27.9 | 97.46 | 0.43 |
| Biological yield (g/plant) | 125.30 | 26.9 | 0.6 | 22.8 | 99.18 | 0.14 |
| Growth rate (g/day/ plant) | 0.849 | 5.5 | 2.7 | 21.4 | 99.06 | 3.16 |

## CONCLUSIONS

The heterotic and combining ability analysis showed that all the studied characters reaveled superiority of dominance effects. The variation of the hybrids was highly significant for all the studied traits, indicating that the genetic and geographical divergence between the parental strains involved in the hybridization process. Heterosis breeding makes utilize of the non-additive gene actions seems more difficult to improve oat due to the non-availability of mass pollination systems/male sterility systems necessary for hybrid seed production. correspondingly, the convenient alternative is to exploit both additive and non-additive gene effect through the recurrent selection. Moreover, the results of present study suggested that heterosis associated with high SCA effects could be take into consideration as standard for selecting hybrid to improve forage trait

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# القدرة على التآلف وقوة الهجين لمحصول العلف والصفات المرتبطة الأخرى في محصول الشوفان


**محمد عمر حمدون الجحيشي ، عبد الحميد محمد علي عكاز، محمد عبد الستار الحناوي و عز الدين إبراهيم حسن زعزع**

**قسم المحاصيل - كلية الزراعة – بالقاهرة - جامعة الأزهر - جمهورية مصر العربية**



هدفت الدراسة، إلى تقدير قدرة التآلف ( العامة والخاصة) وقوة الهجين لخمسة عشر هجينًا تم الحصول عليهم بتزاوج ستة أصناف (الجودا، أناتوليا، إيكاردا طويل، كنجارو، بحوث11 وشفاء) بنظام التزاوج النصف دائري. تم انتخاب هذه الأصناف بناءًا على التباعد الجغرافي فيما بينها وأيضا على الأداء الحقلي تحت الظروف المصرية. طبّقت التجربة بتصميم القطاعات العشوائية الكاملة وبثلاثة مكررات. نفّذت التجربة على أرض حديثة الإستصلاح في مزرعة التجارب التابعة لقسم المحاصيل، كلية الزراعة، جامعة الأزهر بالقاهرة، خلال الموسمين الشتويين 2019/2018 و2020/2019. قيّمت الهجن وآبائها من خلال دراسة ست صفات حقلية: عدد أيام حتى 50% تزهير، عدد أيام حتى 75% نضج، ارتفاع النبات عند النضج، عدد الأشطاء، محصول المادة الجافة ومعدل النمو للنبات. أظهر تحليل التباين وجود فروق معنوية بين الهجن لجميع الصفات تحت الدراسة. أيضا كانت هناك فروق معنوية ما بين الهجن وآبائها لجميع الصفات تحت الدراسة. كانت التباينات الراجعة للقدرتين العامة والخاصة على التآلف عالية المعنوية لجميع الصفات تحت الدراسة. كانت تقديرات التباين الراجعة للفعل الجيني غير الإضافي أعلى من التباين الإضافي لجميع الصفات. أظهر الصنف ايكاردا طويل قدرة على التآلف عالية وموجبة مقارنة بالأصناف الأخرى لصفة محصول المادة الجافة وبقية الصفات الأخرى المدروسة. بيّنت نتائج القدرة الخاصّة على التآلف أنّ الهجينين (إيكاردا x بحوث) و (الجودا x بحوث) أظهرا قدرة خاصّة على التآلف عالية وموجبة لصفة محصول المادة الجافة وبعض الصفات المرتبطة بها. الهجن التي تميّزت في قدرتها الخاصّة على التآلف: (بحوث x شفاء) لصفة ارتفاع النبات عند النضج، (أناتوليا x بحوث) لصفة عدد الأشطاء. أظهرت نتائج الدراسة أنّ جميع الهجن قد أعطت قوة هجين عالية وموجبة لصفة محصول المادة الجافة. سجّلا الهجينين (الجودا x بحوث) و(إيكاردا x بحوث) أفضل قوة هجين لصفة محصول المادة الجافة، وأيضا سجّلا قوة هجين عالية وموجبة لصفة ارتفاع النبات عند النضج ومعدل النمو للنبات. تميّزت الهجن (بحوث x شفاء)، (كنجارو x بحوث) و (أناتوليا x بحوث) بإعطاء قوة هجين عالية وموجبة لصفة عدد أيام حتى 50% تزهير وعدد أيام حتى 75% نضج وعدد الأشطاء، بالتتابع.