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Hybrids Selection of Sunflower Based on Economic Heterosis

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ABSTRACT

The present study on Sunflower (*Helianthus annuus* L.) was carried out with 33 sunflower hybrids at AICRP-Sunflower, Nimpith centre, along with the Bidhan Chandra Krishi Viswa-vidyalaya, Nadia, West Bengal in two subsequent years, 2020-21 & 2021-22 for selecting high-yielding sunflower hybrids on the basis of yield related traits and economic heterosis analysis. The present attempt has been made in the estimation of economic/standard heterosis for oil content (%), seed and oil yield traits in sunflower. In the present study,the highest oil content (%) was recorded by the sunflower hybrid, P-89-1A x EC-601745(43%) and P-89-1A x TSG-303 (42.7%) followed by CMS-38A x TSG-289 (41.2%), P-89-1A x R-1-1(40.4%) and P-89-1A x R-297 and CMS-38A x R-297(40.1%) respectively as compared to the check LSFH-171(32.4%). From the study of economic heterosis, the higher seed yield was found in only one sunflower hybrid, CMS-103A x R-6D-1 and the higher oil yield (kg/ha) was recorded in the sunflower hybrids, CMS-38A x R-297 followed by CMS-103A x R-6D-1, P-89-1A x R-1-1, CMS-302A x R-297, CMS-38A x TSG-289 and CMS-38A x EC-603021 respectively against National check hybrid, LSFH-171.The hybrids with the crosses of the six parents, *viz.* female CMS-38A and CMS-P-89-1A and the male line R-297, EC-623021, TSG-289 and TSG-303 had significant positive hybrid vigour then the rest of the crosses for seed yield and some other yield components like head diameter, 100 seed weight and volume weight (g/100cc) and oil content(%) depicted that above said genotypes appeared to possess high concentration of non-additive genes for seed yield and component traits and, therefore, these parents can be considered as the good combiners for heterosis breeding programme for seed and oil yield improvement in Sunflower.

Key words : *Hybrids, Sunflower, Economic heterosis*

Introduction

Sunflower (*Helianthus annuus* L.), popularly known as 'Suraj Mukhi', is a member of the family Compositae an important oilseed crop with chromosome number 2n =34. Sunflower is the third major oilseed crop in the world after soybean and rapeseed and mustard. It also occupies the fourth position in India after groundnut, rapeseed and mustard, and soybean. Sunflower contains 40 to 52% of good quality oil and a high amount of quality protein in the cake. The oil of the sunflower is light yellow in color and possesses a good odor that can be used for cooking. The oil is also used in the manufacture of hydrogenated oil. Sunflower contribution towards attaining self-sufficiency in edible oil as well as to "yellow revolution" in the country is noteworthy (Mangala Rai, 2002). Unlike groundnut and

([1]Research Scholar, [2]Junior Breeder, [3]Professor) mustard oil sunflower oil is considered premium because of its high PUFA (Polyunsaturated fatty acid) content and vitamin E. High level of linoleic acid and low oleic acid content in sunflower oil reduces the level of blood cholesterol, a factor which is responsible for the incidence of coronary heart disease in human being. Moreover, it is also suitable for deep fat frying due to its high smoking point. The high tocopherol (an antioxidant) content of sunflower oil increases its storability for a long period. Sunflower oil is also used for the preparation of certain paints, varnishes, and plastics because of its good semi-drying properties. Besides, the oil is also used in the manufacture of soaps and detergents. Oil cake is also used as an animal food and in the manufacture of baby foods due to its high protein content. Sunflower is grown over an area of more than 25 million ha in about 70 countries with a world average yield of 1637 kg/ha. Though sunflower has got much more advantages over other oil seed crops in area, production, and productivity, the crop islower than them owing to the following constraints - The unavailability of suitable varieties/ hybrids with diverse duration and high yield potential is the major constraints for low productivity and Lackof quality seeds of improved varieties/ hybrids. During last few years intensive research work has been initiated in India to improve yield as well as quality of oil seed. As yield is very complex character and it is the result of interaction of number of factors inherent to plants and environment in which it is grown it becomes difficult for plant breeders to evaluate and select for this complex polygenic trait. Various components of yield are more or less simply inherited and therefore, more amenable to improve through selection.

Sunflower hybrid breeding was started economically in discovering CMS by Leclercq in 1960. First sunflower hybrids were produced in US in 1972 and reached 80% of production in five years (Miller and Fick, 1997). First sunflower hybrids were produced in US in 1972 and reached 80% of production in five years (Miller and Fick, 1997). Availability of CMS and fertility restoring sources and highly cross pollinated nature of sunflower crop has made the exploitation of heterosis possible on commercial scale. In India, the first sunflower hybrid BSH-1 (CMS-234A x RHA-274) was released for commercial cultivation in India by University of Agricultural Sciences, Bangalore (Seetharam *et al.,* 1980). Since then many 29 hybrids have been released by public sectors which are in commercial cultivation (Sujatha *et al.,* 2019). Availability of CMS and fertility restoring sources and highly cross pollinated nature of sunflower crop has made the exploitation of heterosis possible on commercial scale. During last few years intensive research work has been initiated in India to improve yield as well as quality of oil seed. As yield is very complex character and it is the result of interaction of number of factors inherent to plants and environment in which it is grown it becomes difficult for plant breeders to evaluate and select for this complex polygenic trait.

Though sunflower has got much more advantages over other oil seed crops area, production and productivity of the crop is lower than them owing to following constraints.

- Unavailability of suitable varieties/hybrids with diverse duration and high yield potential is the major constraints for low productivity.
- Lack of quality seeds of improved varieties/ hybrids.

Yield stagnation is the vital concern for making sunflower a competitive and efficient oil seed crop in the country. Furthermore, the present-day hybrids are medium duration and suitable for a number of situations, but hybrids of early (75-80 days) and late duration (110-120 days) are also required for accommodating sunflower in different agro climatic niches and cropping systems.

The present investigation is therefore undertaken to select superior sunflower hybrids using an analysis of economic heterosis.

Materials and Methods

The present investigation was carried out during the Rabi season, 2020-21 and 2021-22 at AICRP-Sunflower, Nimpith centre, 24 Parganas (S),West Bengal and Teaching Farm, Mondouri, Bidhan Chandra Krishi Viswa-Vidyalaya, Nadia, West Bengal-741252. The experimental material for the evaluation and selection consisted of 33 hybrid and one national check Hybrid (LSFH-171) of sunflower (*Helianthus annuus* L.) collected from AICRP-Sunflower, Nimpith centre, 24 Parganas (S), West Bengal-743338. Thirty-four hybrids were sown in Randomized Block Design with three replications during Rabi season in 2020-21 and 2021-22 with a spacing of 60 x 30 cm having three rows of 3.0 m length. Sowing was done by dibbling 1-2 seeds at each hill. Thinning was done 14 days after sowing and only one healthy plant was kept at each hill. After 30 days from sowing the crop was top dressed with urea @ 30 kg N/ha timely and proper cultural practices were carried out to ensure satisfactory crop growth. Observations were recorded on five randomly selected plants, from the middle of each treatment in each replication. The term heterosis was first used by Shull in 1914. Heterosis may be defined as the superiority of an F_1 hybrid over both its parents in terms of yield or some other characteristics. The commercial usefulness of a hybrid would primarily depend on its performance in comparison to the best commercial variety of the concerned crop species. So, in this case, hybrids selection was done using the formula of economic heterosis, Economic heterosis $= \frac{F1-CC}{CC} \times 100$; Where, F1 = Mean value of traits of a hybrid, CC= Mean value of traits of a commercial check.

The present investigation entitled "Study of genetic variability in sunflower hybrid" is therefore undertaken with following objectives:

- To select good sunflower hybrid using economic heterosis.
- To reduce the gap between production and requirements of sunflower through selecting new hybrids.

Results and Discussion

Identification of superior parents for hybridization is an important step in plant breeding. Attaining higher standard heterosis for oil content (%) and oil yield in the experimental hybrids depends on the use of CMS lines and tester lines involved in the hybridization program. The presence of high heterosis in certain crosses and low in others suggested that the nature of gene action varied with the genetic architecture of the parents. Though, heterotic vigour could be exploited by development of hybrids but commercialization of hybrids depends on the superiority over the standard checks (hybrids). In other words, the standard heterosis of the newly developed hybrids is of prime importance for its adoption by farmers. The present attempt has been made in the estimation of standard heterosis for seed yield and important components.

Heterotic vigor could be exploited by the development of hybrids, but the commercialization of hybrids depends on the superiority over the standard checks (hybrids). In other words, the economic or standard heterosis of the newly developed hybrids is of prime importance for its adoption by farmers. The present attempt has been made in the estimation of economic/standard heterosis for oil yield.

For seed yield (kg/ha), only one hybrid *i.e.,* CMS-103A x R-6D-1 (2336 kg/ha) significantly manifested higher seed yield against the national check hybrid LSFH-171 (2259 kg/ha). Chandra *et al.* (2013) also reported the heterosis in sunflower for seed yield and its components in sunflower hybrids over locations. The highest oil content (%) was recorded

Table 1. Economic heterosis for oil content (%) and oil yield (kg/ha) over standard check hybrid.

Name of the Hybrid	Seed yield (kg/ha)	Economic heterosis of Seed yield (kg/ha) over check (LSFH-171) (in %)	Oil cont. (%)	Economic heterosis of Oil content (%) over check (LSFH-171) (in %)	Oil yield (kg/ha)	Economic heterosis of Oil yield (kg/ha) over check (LSFH-171) (in %)
CMS-38A x R-297	2212.7	-2.0	40.0	23.5**	869.7	18.3**
CMS-103A x R-6D-1	2336.7	3.4*	36.7	13.3**	857.4	16.7**
P-89-1A x R-1-1	2085	-7.7	40.4	24.7**	843.9	14.8**
CMS-302A x R-297	2068	-8.5	38.4	18.5**	808.4	10.0**
CMS-38A x TSG-289	1900	-15.9	41.2	27.2**	796.0	8.3*
CMS-38A x EC-603021	1976	-12.5	38.3	18.2**	765.9	4.2
P-89-1A x TSG-303	-	-	42.7	31.8**	603.8	-17.9
P-89-1A x EC-601745	-	-	43.0	32.7**	584.3	-20.5
P-89-1A x R-297	-	-	40.1	23.8**	745.1	1.4
LSFH-171	2259	-	32.4	-	734.0	-

*, **: Significant at 5% and 1% level respectively

by the sunflower hybrid, P-89-1A x EC-601745(43%) and P-89-1A x TSG-303 (42.7%) followed by CMS-38A x TSG-289 (41.2%) , P-89-1A x R-1-1(40.4%) and P-89-1A x R-297 and CMS-38A x R-297(40.1%) respectively as compared to the check LSFH-171 (32.4 %). The sunflower hybrids, P-89-1A x EC-601745 and P-89-1A x TSG-303, CMS-38A x TSG-289, P-89-1A x R-1-1, P-89-1A x R-297, CMS-38A x R-297 were recorded 32.7 %, 31.8%, 27.2 %, 24.7 %, 23.8% and 23.5% respectively higher oil content (%) compared to the National heck hybrid, LSFH-171.

The highest oil yield (kg/ha) was recorded by CMS-38A x R-297 (869 kg/ha) followed by CMS-103A x R-6D-1 (857 kg/ha), P-89-1A x R-1-1 (843 kg/ha), CMS-302A x R-297 (808 kg/ha), CMS-38A x TSG-289 (796 kg/ha), CMS-38A x EC-603021 (756 kg/ha) respectively as compared to the check LSFH-171 (734 kg/ha). The sunflower hybrids, CMS-38A x R-297, CMS-103A x R-6D-1, P-89-1A x R-1-1, CMS-302A x R-297, CMS-38A x TSG-289 were recorded 25.3 %, 13.3%, 24.7 %, 18.5 %, 27.2% and 8.3% respectively higher oil yield (kg/ha) compared to the check hybrid, LSFH-171. Lakshman *et al.* (2021), Archana *et al.* (2018) and Asif *et al.* (2013) also re-

Table 2. Mean performance of sunflower hybrids

Name of Entry	OC%	SY/P (g)	OY/P (g)	SY (kg/ha)	OY (kg/ha)
CMS-38A x EC-601901	38.2	29.0	11.2	1609.7	621
CMS-38A x EC-603021	38.3	35.6	13.8	1976	765.9
P-89-1A x TSG-303	42.7	25.6	10.9	1424.7	603.8
P-89-1A x TSG-321	38.5	22.7	8.7	1263.7	485.9
CMS-38 A x EC-601851	34.0	30.2	10.3	1678.3	570.8
CMS-850A x TSG-253	31.8	21.5	6.8	1191.7	379.4
P-89-1A x EC-601745	43.0	24.2	10.5	1343.3	584.3
CMS-38A x EC-623021	33.8	37.9	12.6	2104	697.3
CMS-302A xEC-601836	34.8	19.0	6.6	1056.3	367.7
P-89-1A x EC-623021	37.0	29.3	11.0	1629.7	608.7
CMS-38 A x R-35	35.5	29.2	10.3	1622.7	574.9
CMS-38A x R-138-2	37.1	26.9	10.0	1496.7	552.9
CMS-67A x EC-623021	30.7	31.5	9.6	1751.7	532.2
CMS-67A xTSG-289	35.7	21.8	7.7	1210	428.4
CMS-38A x TSG-289	41.2	34.2	14.3	1900	796
CMS-850A x TSG-316	35.8	29.1	10.4	1616.7	578.1
P-89-1A x R-630	31.7	32.7	10.4	1818.7	576.5
CMS-850 A x EC- 601901	38.1	25.4	9.7	1413.3	538.5
P-89-1A x EC-601623	36.7	22.1	8.1	1226.3	449.8
CMS-38A xTSG-328	39.8	28.0	11.2	1557.7	620.3
CMS-234 A X R-297	37.1	34.9	13.0	1938.7	720
P-89-1A x R-6D-1	32.0	33.4	10.7	1857.3	594.6
P-89-1A x R-1-1	40.4	37.5	15.2	2085	843.9
CMS-850A x R-6D-1	36.8	28.8	10.6	1600.3	587.8
CMS-302A x R-297	38.4	37.2	14.6	2068	808.4
CMS-850A X R-297	35.3	26.8	9.5	1491	526.5
CMS-302A xEC-601958	37.4	30.2	11.4	1679.7	632.1
CMS-234A xR-1-1	35.6	26.4	9.4	1465	520.8
CMS-103A xR-6D-1	36.7	42.1	15.4	2336.7	857.4
CMS-38A x R-297	40.0	39.8	15.7	2212.7	869.7
CMS-103A x R-297	35.7	32.9	11.8	1829.7	653.9
P-89-1A x R-297	40.1	33.4	13.4	1858	745.1
KBSH-84	35.6	33.0	11.7	1835	652.4
LSFH-171	32.4	40.7	13.2	2259	734
Gr.Mean	36.61	30.51	11.11	1694.7	619.16
CD(P=0.005)	1.2	2.9	1.3	164.1	65.1
CV (%)	1.9	5.9	7.3	5.9	6.4

OC(%) = Oil content %, SY/P (g) = Seed Yield/Plant(g), OY/P (g) = Oil yield/plant (g) ported the heterosis in sunflower for seed yield and its components in sunflower hybrids int the experiment of combining ability study. These results were in conformity with the earlier findings of Binodh *et al.* (2008), Manivannan *et al.* (2005), Tavade *et al.* (2009), Tyagi *et al.* (2020) and Haddadan *et al.* (2020). Our findings are in agreement with Mohanasundaram *et al.* (2010) and Parameshwarappa *et al.* (2008).

Identification of superior parents for hybridization is an important step in plant breeding. Attaining higher standard heterosis for seed, oil content (%) and oil yield in the experimental hybrids depends on the use of CMS lines and tester lines involving in the hybridization programme. Presence of high heterosis in certain crosses and low in others suggested that the nature of gene action varied with genetic architecture of the parents. Earlier many research workers *viz.,* Sujatha *et al.* (2019), Tavade *et al.* (2009), Manivannan *et al.* (2005), Halaswamy *et al.* (2004), and also reported good general combiners played a pivotal role for seed and oil yield improvement in sunflower.

The hybrids with the crosses of the six parents, *viz.* female CMS-38A and CMS-P-89-1A and the male line R-297, EC-623021, TSG-289 and TSG-303 had significant positive *hybrid* vigour then the rest of the crosses for seed yield and some other yield components like head diameter, 100 seed weight and volume weight (g/100cc) and oil content(%) depicted that these genotypes appeared to possess high concentration of non-additive genes for seed yield and component traits and, therefore, these parents can be considered as the good combiners for heterosis breeding programme for seed and oil yield improvement in sunflower. Many researcher *viz.,* Haddadan *et al.* (2020), Jondhale *et al.* (2014), Manivannan *et al.* (2005) and Halaswamy *et al.* (2004) reported good general combiners in sunflower for most of the seed yield and attributing characters under study. The significant positive heterosis of hybrids based on diverse CMS system over national check hybrid DRSH-1 was also reported by Lakshman *et al.* (2018). Prevalence of significant standard heterosis for seed yield has also been reported by Manivannan *et al.* (2015), Lakshman *et al.* (2021) and Thakare *et al.* (2015). Attaining higher standard heterosis for seed yield in the experimental hybrids with the use of CMS lines /tester lines have also been made by Meena *et al.* (2013). Positive standard heterosis was observed for seed yield and oil content by Rathi *et al.* (2016) and Tyagi *et al.* (2013). Supriya *et al.* (2019) and Sahane *et al.* (2017). noticed the standard heterosis of for seed yield and for oil content in sunflower and opined that the economic heterosis of sunflower for seed yield and for oil content may be due divergence of CMS and restorer Sources. Generally the per se performance of the parents is found to be closely related with high heterotic hybrids. There was desirable shift in mean performance from parents to hybrids in almost all the characters under study. Presence of high heterosis in certain crosses and low in others suggested that the nature of gene action varied with genetic architecture of the parents.

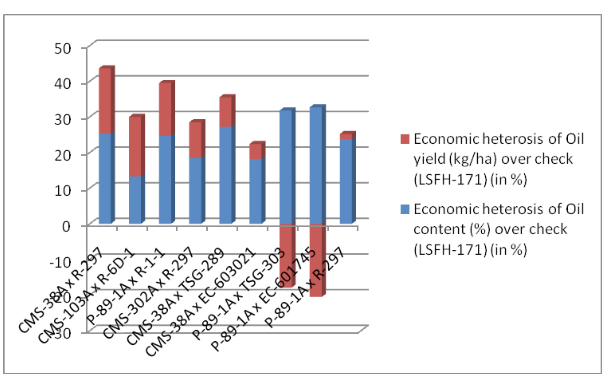

Fig. 1. Graphyics of Economic heterosis for oil content (%) and oil yield (kg/ha) over DRSH-1

Conclusion

The results of the economic heterosis study indicate that the research work should be focused for the development of new high-yielding stable sunflower hybrids which might be based on the hybridization between the best diverse combiners. The hybrids with the crosses of the six parents, *viz.* female CMS-38A and CMS-P-89-1A and the male line R-297, EC-623021, TSG-289 and TSG-303 had significant positive hybrid vigour then the rest of the crosses for seed yield and some other yield components like head diameter, 100 seed weight and volume weight (g/100cc) and oil content(%) depicted that above said genotypes appeared to possess high concentration of non-additive genes for seed yield and component traits and, therefore, these parents can be considered as the good combiners for heterosis breeding programme for seed and oil yield improvement in Sunflower.

The highest oil content (%) was recorded by the sunflower hybrids, P-89-1A x EC-601745(43%) and

P-89-1A x TSG-303 (42.7%) followed by CMS-38A x TSG-289 (41.2%), P-89-1A x R-1-1(40.4%) and P-89-1A x R-297 and CMS-38A x R-297(40.1%) respectively as compared to the check LSFH-171 (32.4 %). The sunflower hybrids CMS-38A x R-297, CMS-103A x R-6D-1, P-89-1A x R-1-1 and CMS-302A x R-297 significantly manifested highest oil yield (kg/ha) against national checks hybrid LSFH-171.

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References

Archana, W., Thorat, E.R., Vaidya, V.R., Gupta, Swati P., Bharsakal and Vandana Mohod, 2018. Combining ability and gene action studies for yield and its component in sunflower (*Helianthus annuus* L.). *Int. J. Curr. Microbiol. App. Sci.* 6: 598-605.

Asif, M., Shadakshari, Y.G., Naik, S.J.,Venkatesha, S., K.T. Vijayakumar and Basavaprabhu, K. V. 2013. Combining ability studies for seed yield and it's contributing traits in sunflower (*Helianthus annuus* L.). *International Journal of Plant Sciences.* 8(1): 19-24.

Binodh, A.K., Manivannan, N. and Vindhya Varman, P. 2008. Combining ability analysis for yield and its contributing characters in sunflower (*Helianthus annuus* L.). *Madras Agricultural Journal.* 95 (7-12): 295-300.

Chandra, B.S., Ranganatha, A.R.G. and Kumar, S.S. 2013. Heterosis studies for seed yield and its components in sunflower hybrids over locations. *Madras Agricultural Journal.* 100(1-3): 23-29.

Darvishzadeh, R. 2012. Phenotypic and molecular marker distance as a tool for prediction of heterosis and F1 performance in sunflower (*Helianthus annuus* L.) under well-watered and water-stressed conditions. *Australian Journal of Crop Science.* 6(4): 732-738.

Haddadan, A.Z., Ghaffari, M., Hervan, E.M. and Alizadeh, B. 2020. Impact of parent inbred lines on heterosis expression for agronomic characteristics in sunflower. *Czech Journal of Genetics and Plant Breeding.* 56(3): 123–132.

Halaswamy, K.M., Channakrishnaiah, S. and Kulkarni, R.S. 2004. Combining ability in sunflower (*Helianthus annuus* L.). *Crop Res.* 28(1, 2 and 3): 103-112.

Jondhale, A.S., Shanker Goud, I. and Praveenkumar, B. 2014. Combining ability and gene action studies in diverse CMS sources in sunflower (*Helianthus annuus* L.). *International Journal of Science and Research.* 3: 2183-2187.

Leclercq, P. 1969. Line sterile cytoplasmic quechezktournesol. *Ann. Amelior Planta.* 12: 99-106.

Lakshman, S.S., Chakrabarty, N.R. Godke, M.K. and Kole, P.C. 2020. Heterosis Study in Sunflower (*Helianthus annuus* L.) Hybrids for Yield Attributing Traits in High Salinity Condition for Identification of Superior Sunflower Hybrids for Coastal Saline Belts. *European Jr. of Exp. Bio.* 10(12):1-14.

Lakshman, S.S., Godke, M.K., Chakrabarty, N.R. and Kole, P.C. 2018. Studies on Heterosis for seed yield and yield attributing traits in sunflower (*Helianthus annuus* L.) in high saline soil of West Bengal. *Journal of Crop and Weed*. 14(1): 91-99.

Lakshman, S.S., Godke, M.K. and Kar, J. 2021. Estimation of economic heterosis for seed and oil yield in sunflower (*Helianthus annuus* L.) hybrids for coastal saline belt. *Electronic Journal of Plant Breeding.* 12(2): 335-341.

Lakshman, S.S., Chakrabarty, N.R. and Kole, P.C. 2018. Economic Heterosis for seed and oil yield in sunflower (*Helianthus annuus* L.) hybrids over locations in heterosis breeding West Bengal. *Indian Agriculturist.* 62(1&2): 1-8.

Mangala Rai, 2002. Oilseeds in India. *Andhra Pradesh Agric. Reg. Res. J.* 13-15.

Manivannan, N., Vidhyavathi, P. and Muralidharan, V. 2005. Diallel analysis in sunflower. *Indian Journal of Agricultural Research.* 39(4): 281-285.

Miller, J. and Fick, G.N. 1997. The genetics of sunflower. p. 491-495. In: A.A. Schneiter (ed.) *Sunflower Technology and Production.* Agronomy Monography 35. ASA, CSSA and SSSA, Madison, WI, USA.

Manivannan, N., Chandirakala, R. and Abirami, S. 2015.. Evaluation of new CMS lines for heterosis breeding in sunflower (*Helianthus annuus* L.). *Advances in life Sciences.* 5(5): 1909-1912.

Meena, C.R., Meena, H.P. and Snha, B. 2013. Fertility restoration, combining ability effects and heterosis in sunflower (*Helianthus annuus* L.) using different CMS sources. *Chilean J. Agric. Res.* 17(99): 101-104.

Memon, S., Baloch, M.J., Baloch, G.M. and Keerio, M.I. 2014. Heritability and correlation studies for phenological, seed yield and oil traits in sunflower (*Helianthus annuus* L.). *Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences.* 30(2): 159-171.

Mijiæ, A., Lioviæ, I., Kovaèeviæ, V. and Pepó, P. 2012. Impact of weather conditions on variability in sunflower yield over years in eastern parts of Croatia and Hungary. *Acta Agronomica Hungarica.* 60(4): 397-405.

Mohansundaram, K., Manivannan, N. and Vindhaiyavarman, P. 2010. Combining ability analysis for seed yield and its components in sunflower (*Helianthus annuus* L.). *Elec. J. Pl. Breed.* 4: 864-865.

Panse, V.G. and Sukhatme, P.V. 1954. *Statistical Methods for Agricultural Workers*.

Parameshwarappa, K.G., Jalandhar Ram and Lingaraju, B.S. 2008. Heterosis and combining ability for seed yield, oil content and other agronomic traits involving mutant restorer lines in sunflower (*Helianthus annuus* L.). J. *Oilseeds Res.* 25(1): 8-12.

Sahane, G.S., Nichal, S.S., Vaidya, E.R. and Girnare, V.B. 2017. Heterotic studies in Sunflower (*Helianthus annuus* L.) through Line x Tester analysis. *Trends in Bio-Science.* 10(42): 8778-8788.

Sujatha, M. and Reddy, A.V. 2009. Heterosis and combining ability for seed yield and other yield contributing characters in sunflower (*Helianthus annuus* L.). *Journal Oilseeds Research.* 26(1):21-31.

Seetharam, A., Giriraj, K. and Kusuma Kumari, P. 1980. Phenotypic stability of seed yield in sunflower hybrids. *Indian J. Genet.* 40: 102-104.

Sujatha, M., Meena, H.P., Mukta, N. and Vishnuvardhan Reddy, A. 2019. Varieties and Hybrids of Sunflower. ICAR-Indian Institute of Oilseeds Research, Hyderabad 60 P.

Thakare, S.U., Nichal, S.S., Ingle, A.U. and Tayade, S.D. 2015. Heterosis studies for yield contributing traits and oil content in sunflower (*Helianthus annuus* L.). *Trends in Bio-Sci*. 8 (12): 3010-3017.

Tyagi, N., Dhillon, S.K. and Bajaj, R.K. 2013. Estimates of heterosis for oil content in sunflower (*Helianthus annuus* L.). In: *Proceedings of 16th Punjab Science Congress,* pp 72.