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Correlation and Path Analysis Studies in Chilli

A.D. Warade[1], Mahesh[2], S. R. Dalal[3], S. M. Ghawade[4] and Pravina Satpute[5]

ABSTRACT

The present investigation consisted of 20 genotypes carried out at Department of Vegetable Science, Dr. PDKV, Akola. The estimate of genotypic correlation coefficients in general higher than their corresponding phenotypic correlations indicating strong inherent association among the traits. The character fruit yield plant^{-1} was positively and significantly correlated with plant height, primary branches plant^{-1}, fruit length, number of fruits plant^{-1} and fruit diameter at both genotypic and phenotypic levels. However, It showed non-significant association with the characters, days to 1st flower initiation (0.2316), days to 50 per cent flowering (0.0901), number of seeds fruit^{-1} (0.3562) at genotypic level. These characters can be considered as criteria for selection for higher yield, as these were mutually and directly associated with fruit yield. The genotypic path coefficient analysis indicated that, plant height, primary branches plant^{-1}, number of seeds fruit^{-1}, pericarp thickness, number of fruits plant^{-1} and fruit weight had positive and direct effect on fruit yield plant^{-1}. Hence, a direct selection for this trait would be effective.

Chilli (*Capsicum annuum* L.) is a spice cum vegetable crop belonging to the family Solanaceae with chromosome number 2n = 24. It is native of Mexico, which was brought into India from Brazil by Portuguese prior to 1785 AD. It can be regarded as universal spice of India. Crop improvement in chilli has so far been achieved by exploiting the available sources of the variability.

Naturally, the genetic variation or diversity for most of the yield attributes is considerably high in chilli. There is a need to seek improvement in complex quantitative trait such as yield. As a result of free exchange of chilli germplasm and lot of introgressions of characters has taken place in many local chilli cultivars resulting in enhancement of variability and new genetic combinations.

To know the extent of variability present in a population, evaluation of large number of germplasm lines is the first step. This improvement in any crop is based on the extent of genetic variation and magnitude of available beneficial genetic variability. The proportion of genotypic, environmental variance and their interaction (G × E), can be determined by employing useful biometrical and genetical methods. Some of these parameters include genotypic (GCV) and phenotypic (PCV) coefficients of variation. Genotypic and phenotypic correlations reveal the degree of association between different characters. The other genetic parameter commonly used is the path analysis as given by Dewey and Lu (1959). Path analysis gives the cause-and-effect relationship. It critically breaks up different direct effect and indirect effects which finally makes up correlation coefficient. In this study genotypic and phenotypic path for yield per plant was analysed by selecting most influencing independent variables.

Genetic variability is a crucial pre-requisite in any breeding material, as it serves as the foundation for selection and provides valuable insights for choosing diverse parents for hybridization programs. A plant breeder's primary task is to identify sources of favourable genes, incorporate them into breeding populations, and aim to isolate productive genotypes and cultivars.

Hence, the present study was undertaken to analyse the extent of corelation present in twenty germplasm lines of chilli in respect of traits contributing to yield and quality of chilli fruits.

MATERIAL AND METHODS

The experiment was conducted at Chilli and vegetable research unit, Dr. PDKV, Akola in Maharashtra, in Kharif season of 2023-24. Twenty genotypes were examined under research including two checks Jayanti and PDKV-Hirkani. The accession numbers of the genotypes with codes are given in Table 1. The germplasm accessions raised were raised in the main field in randomized block design with three replications om broad bed furrow. A spacing of 60 cm × 60 cm was followed and the crop was raised as per the recommended package of practices. Five random competitive plants treatment^{-1}

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genotypes^{-1} were selected, tagged and observations were recorded on these plants for different characters like, growth, earliness, fruit, yield, seed and quality parameters.

RESULTS AND DISCUSSION

Correlation studies

Correlation studies play a crucial role in breeding programs aimed at genetic improvement. They assess the relationship between two or more traits, providing insights into how various plant characteristics are associated. This information is vital for determining which traits can be effectively selected to enhance yield and other desirable features across diverse genotypes. Understanding these interactions helps breeders make informed decisions, optimizing the selection process for various traits and improving overall genetic outcomes. The data regarding genotypic correlation are presented in Table 2 and phenotypic correlation in Table 3.

At genotypic level, fruit yield per plant has shown significant and positive correlation for plant height, number of primary branches plant^{-1}, number of fruits plant^{-1}, fruit weight, fruit length, number of seed plant^{-1}, and fruit diameter and fruit weight. It has positive correlation with days taken to first flowering, days to 50 per cent flowering, number of seeds fruit^{-1}, but negatively correlated with days to first picking and Length of pedicel, seed recovery percentage and pericarp thickness. Consistent with the results of Tembhurne and Rao (2013), Yatung *et al*. (2014), Amit *et al*. (2014), Singh *et al*. (2014), Patel *et al*. (2015), Rohini and Lakshmanan (2015), Rana *et al*. (2015), Bijalwan and Madhvi (2016), and Pujar *et al*. (2017), found significant positive correlation between fruit yield per plant and several traits including fruit length, average fruit weight, and number of fruits per plant. This corroborates the general understanding that these parameters are crucial contributors to the yield potential in chili plants.

The estimates of the genotypic correlation coefficient for different characters of chilli genotypes are presented in Table 2.

At phenotypic level, fruit yield plant^{-1} has shown significant and positive correlation for plant height, number of primary branches plant^{-1}, number of fruits plant^{-1}, fruit weight, fruit length, number of seed plant^{-1}, and fruit diameter and fruit weight. It has positive correlation with days taken to first flowering, but negatively correlated with days to first picking, and Length of pedicel, seed recovery percentage and pericarp thickness. This investigation further supports the findings of Murmu *et al*. (2017), Bharadwaj *et al*. (2007), Sharma *et al*. (2010), and Chattopadhyay *et al*. (2011). Additionally, Vidya *et al*. (2018) highlighted the importance of fruit girth in enhancing green fruit yield plant^{-1}, a result consistent with our observations. However, our results extend these findings by showing a significant positive correlation between fruit yield and pericarp thickness, suggesting that fruit quality parameters also play a role in yield.

The estimates of the phenotypic correlation coefficient for different characters of chilli genotypes are presented in Table 2.

Path coefficient analysis

The correlation coefficient indicates a simple correlation between variables. However, relationships in biological systems can be quite complex. Therefore, a comprehensive study of the relationship between variables is necessary. Path coefficient analysis is a highly powerful technique that enables us to break down these relationships into their constituent component.

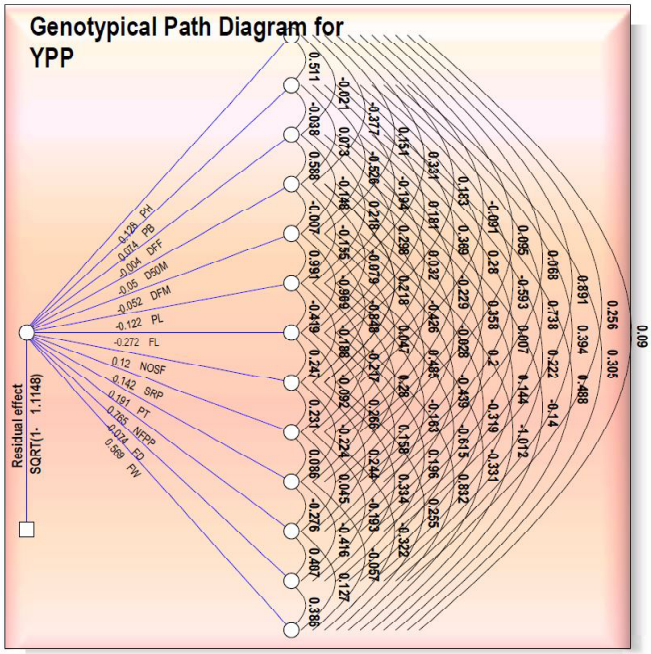
Genotypic path coefficients were computed for all yield-attributing characters to evaluate both direct and indirect effects of a trait on economic yield performance. Yield was apportioned into direct and indirect correlations based on the correlation coefficients observed between yield and contributing traits. In this study, fruit yield plant^{-1} was used as a reliable variable alongside other parameters. This finding is consistent with previous research highlighting these traits as critical determinants of yield by Pal and Rani (1996), Negi and Sharma (2019), Tembhurne and Rao (2013), Patel *et al*. (2015), Gorka *et al*. (2016), Pujar *et al*. (2017), Murmu *et al*. (2017) and Vidya *et al*. (2018). The table 3. presents the direct and indirect effects of various traits on pod fruit yield plant^{-1} and depicted in Fig. 1.

CONCLUSION

Fruit yield plant^{-1} was found significant and

Table 1. The details of the chilli genotypes used in the study.

S.N.	Genotypes	Abbreviation used	Source
1.	Khurasani	T_1	CVRU, Dr PDKV Akola, Maharashtra
2.	Keshori	T_2	CVRU, Dr PDKV Akola, Maharashtra
3.	Bhivapuri	T_3	CVRU, Dr PDKV Akola, Maharashtra
4.	AKCH-21-01	T_4	CVRU, Dr PDKV Akola, Maharashtra
5.	AKCH-21-02	T_5	CVRU, Dr PDKV Akola, Maharashtra
6.	AKCH-21-03	T_6	CVRU, Dr PDKV Akola, Maharashtra
7.	AKCH-21-04	T_7	CVRU, Dr PDKV Akola, Maharashtra
8.	AKCH-21-05	T_8	CVRU, Dr PDKV Akola, Maharashtra
9.	AKCH-21-06	T_9	CVRU, Dr PDKV Akola, Maharashtra
10.	AKCH-21-07	T_{10}	CVRU, Dr PDKV Akola, Maharashtra
11.	AKCH-21-08	T_{11}	CVRU, Dr PDKV Akola, Maharashtra
12.	AKCH-21-09	T_{12}	CVRU, Dr PDKV Akola, Maharashtra
13.	CHILCVRES-21-10	T_{13}	CVRU, Dr PDKV Akola, Maharashtra
14.	CHILCVRES-21-11	T_{14}	CVRU, Dr PDKV Akola, Maharashtra
15.	CHILCVRES-21-12	T_{15}	CVRU, Dr PDKV Akola, Maharashtra
16.	CHILCVRES-21-13	T_{16}	CVRU, Dr PDKV Akola, Maharashtra
17.	CHILCVRES-21-14	T_{17}	CVRU, Dr PDKV Akola, Maharashtra
18.	CHILCVRES-21-15	T_{18}	CVRU, Dr PDKV Akola, Maharashtra
19.	Jayanti (C)	T_{19}	CVRU, Dr PDKV Akola, Maharashtra
20.	PDKV Hirkani (C)	T_{20}	CVRU, Dr PDKV Akola, Maharashtra



Where,

PH - Plant height (cm)
PB - Primary branches per plant
DFF - Days to 1st flower initiation
D50 - Days to 50% flowering
DFM - Days to first picking
PL - Length of pedicle (cm)
FL - Fruit length (cm)
NOSF - Number of seeds/fruit
SRP - Seed recovery (%)
PT - Pericarp thickness (mm)
NFPP - Number of fruits/plant
FD - Fruit diameter (cm)
FW - Fruit weight (g)
YPP - Fruit yield per plant (kg)

Fig. 1. Genotypic path diagram showing direct and indirect effects of different characters on fruit yield in chilli

Table 2. Genotypic correlation coefficient among growth, yield and quality parameters in Chilli genotypes

	Plant height (cm)	Primary branches plant^{-1}	Days 1st to flower initiation	Days to 50% flowering	Days required for first picking	Length of pedicel (cm)	Fruit length (cm)	Number of seeds fruit^{-1}	Seed recovery percentage (%)	Pericarp thickness (mm)	Number of fruits plant^{-1}	Fruit Diameter (cm)	Fruit weight (gm)	Fruit yield plant^{-1} (kg)
Plant height (cm)	1.000	0.5105*	-0.0212	-0.3768	0.1513	0.3306	0.1832	-0.0911	0.0953	0.0678	0.8914**	0.2557	0.0895	0.7891**
Primary branches per plant		1.000	-0.0378	0.0731	-0.5256*	-0.1942	0.1813	0.3694	0.2801	-0.5927**	0.7377**	0.3936	0.3057	0.7378**
Days to 1st flower initiation			1.000	0.5882**	-0.1477	0.2184	0.2978	0.0318	-0.2290	0.3580	0.0066	0.2225	0.4872*	0.2316
Days to 50% flowering				1.000	-0.0073	-0.1551	-0.0791	0.2178	-0.4256	-0.0278	0.2004	0.1440	-0.1390	0.0901
Days required for first picking					1.000	0.9914**	-0.9695**	-0.8481**	0.0465	0.4848*	-0.4395	-0.3188	-1.0119**	-0.8322**
Length of pedicel (cm)						1.000	-0.4188	-0.1881	-0.2166	0.2803	-0.1629	-0.6152**	-0.3321	-0.2305
Fruit length (cm)							1.000	0.2471	-0.0915	0.2664	0.1584	0.1961	0.8321**	0.5429*
Number of seeds per fruit								1.000	0.2308	-0.2239	0.2437	0.3337	0.2568	0.3562
Seed recovery percentage (%)									1.000	0.0856	0.0454	-0.1934	-0.3223	-0.1283
Pericarp thickness (mm)										1.000	-0.2764	-0.4160	-0.0571	-0.2271
Number of fruits per plant											1.000	0.4068	0.1266	0.9356**
Fruit diameter (cm)												1.000	0.386	0.5363*
Fruit weight (gm)													1.000	0.6094**
Fruit yield per plant (kg)														1.000

**Significant at 1% *significant at 5%

Critical r_g value (at 5%) =**0.542** significant at p= 0.005 Critical r_g(at 1%) =**0.666** Significant at p= 0.001

Table 3.: Phenotypic correlation coefficient among growth, yield and quality parameters in Chilli genotypes

	Plant height (cm)	Primary branches plant^{-1}	Days to1st flower initiation	Days to 50% flowering	Days required for first picking	Length of pedicel (cm)	Fruit length (cm)	Number of seeds fruit^{-1}	Seed recovery percentage (%)	Pericarp Thickness (mm)	Number of fruits plant^{-1}	Fruit Diameter (cm)	Fruit weight (gm)	Fruit yield plant^{-1} (kg)
Plant height (cm)	1.000	0.391**	-0.0606	0.0453	0.0586	0.0761	0.1444	-0.0435	0.0714	-0.0764	0.5237**	0.1742	0.0163	0.4514**
Primary branches per plant		1.000	0.0789	0.079	-0.3047*	-0.1531	0.2263	0.3791**	0.2389	-0.4446**	0.5498**	0.349**	0.2533	0.5969**
Days to 1st flower initiation			1.000	0.1396	0.0127	0.0229	0.2804*	0.1093	-0.0983	-0.0241	-0.0083	0.2089	0.2236	0.1482
Days to 50% flowering				1.000	0.0493	-0.0569	-0.0011	0.0832	-0.2175	-0.0728	0.1004	0.0382	-0.0691	-0.0087
Days required for first picking					1.000	0.1087	-0.4309**	-0.2957*	-0.0248	0.1119	-0.1764	-0.1934	-0.4774**	-0.3592**
Length of pedicel (cm)						1.000	-0.2598*	-0.1102	-0.1027	0.1391	0.0191	-0.2338	-0.1146	-0.0129
Fruit length (cm)							1.000	0.2672*	-0.0725	0.0843	0.1041	0.1995	0.7184**	0.4452**
Number of seeds per fruit								1.000	0.1963	-0.2126	0.2236	0.3158*	0.219	0.3137*
Seed recovery percentage (%)									1.000	0.0213	0.0084	-0.1334	-0.3159*	-0.1233
Pericarp thickness (mm)										1.000	-0.2366	-0.3584**	0.0559	-0.1622
Number of fruits per plant											1.000	0.3413**	0.0887	0.7445**
Fruit diameter (cm)												1.000	0.338**	0.4814**
Fruit weight (gm)													1.000	0.05583**
Fruit yield per plant (kg)														1.000

**Significant at 1% *significant at 5%

Critical r_g value (at 5%) =0.542 significant at p= 0.005 Critical r_g(at 1%) =0.666 significant at p= 0.001

Table 4. Genotypic path coefficient analysis showing direct (diagonal and bold) and indirect effects of different characters on fruit yield in chilli.

	Plant height (cm)	Primary branches plant^{-1}	Days to1st flower initiation	Days to 50% flowering	Days required for first picking	Length of pedicel (cm)	Fruit length (cm)	Number of seeds fruit^{-1}	Seed recovery percentage (%)	Pericarp thickness (mm)	Number of fruits plant^{-1}	Fruit diameter (cm)	Fruit weight (gm)	Fruit yield plant (kg)r_g
Plant height (cm)	0.1275	0.0396	0.0001	0.0192	-0.0079	-0.0416	-0.0517	-0.0110	-0.0137	0.0134	0.6832	-0.0196	0.0516	0.7891**
Primary branches per plant	0.0651	0.0775	0.0002	-0.0037	0.0275	0.0244	-0.0512	0.0446	-0.0405	-0.1177	0.5655	-0.0302	0.1762	0.7378**
Days to 1st flower initiation	-0.0027	-0.0029	-0.0058	-0.0300	0.0077	-0.0274	-0.0841	0.0038	0.0331	0.0711	0.0050	-0.0171	0.2809	0.2316
Days to 50% flowering	-0.0480	0.0056	-0.0034	-0.0510	0.0003	0.0195	0.0223	0.0263	0.0615	-0.0055	0.1536	-0.0110	-0.0801	0.0901
Days required for first picking	0.0192	-0.0407	0.0008	0.0003	-0.0524	-0.1247	0.2738	-0.1024	-0.0067	0.0963	-0.3368	0.0245	-0.5834	-0.8322**
Length of pedicel (cm)	0.0421	-0.0150	-0.0012	0.0079	-0.0520	-0.1258	0.1183	-0.0227	0.0313	0.0557	-0.1248	0.0473	-0.1914	-0.2305
Fruit length (cm)	0.0233	0.0140	-0.0017	0.0040	0.0508	0.0527	-0.2824	0.0298	0.0132	0.0529	0.1214	-0.0150	0.4798	0.5429*
Number of seeds per fruit	-0.0116	0.0286	-0.0001	-0.0111	0.0445	0.0236	-0.0698	0.1207	-0.0333	-0.0444	0.1867	-0.0256	0.1480	0.3562
Seed recovery percentage (%)	0.0121	0.0217	0.0013	0.0217	-0.0024	0.0272	0.0258	0.0278	-0.1446	0.017	0.0348	0.0148	-0.1858	-0.1283
Pericarp thickness (mm)	0.0086	-0.0459	-0.0021	0.0014	-0.0254	-0.0352	-0.0752	-0.0270	-0.0123	0.1988	-0.2117	0.0320	-0.0328	-0.2271
Number of fruits per plant	0.1136	0.0572	-0.0000	-0.0102	0.0230	0.0204	-0.0447	0.0294	-0.0065	-0.0549	0.7665	-0.0313	0.0729	0.9356**
Fruit diameter (cm)	0.0326	0.0305	-0.0013	-0.0073	0.0167	0.0774	-0.0554	0.0402	0.0279	-0.0827	0.3118	-0.0769	0.2225	0.5363*
Fruit weight (g)	0.0114	0.0237	-0.0028	0.0071	0.0531	0.0417	-0.2350	0.0310	0.0466	-0.0113	0.0970	-0.0297	0.5766	0.6094**

Diagonal indicates direct effect RESIDUAL EFFECT = -0.115

r_g- Genotypic correlation with yield per plant

positively correlated with the characters plant height, primary branches plant^{-1}, fruit length, number of fruits plant^{-1}, fruit diameter and fruit weight. The genotypic path coefficient analysis revealed that the characters *viz.,* plant height, primary branches plant^{-1}, number of seeds fruit^{-1}, pericarp thickness, number of fruits plant^{-1} and fruit weight were significant yield contributing characters as they registered high positive and direct effect on fruit yield plant^{-1}.

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Correlation and Path Coefficient Analysis in Sunflower (*Helianthus annuus* L.) Interspecific Derivatives

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ABSTRACT

This study was to evaluate the advanced interspecific derivatives derived from five annual diploid Helianthus species based on phenotypic and genotypic correlation so that we can find out the which trait directly or indirectly effect the yield and quality of the sunflower because being a breeder our main aim is yield and quality and the lines which are performing best can be further used in the breeding programs. path analysis measures the direct and indirect contribution of various independent characters on a dependent character. Therefore, the present investigation was undertaken to determine the mutual association among different traits in sunflower and their direct and indirect effects on yield by using path coefficient analysis. The experimental material for present investigation consisted of 20 advanced interspecific derivatives developed by Indian Institute of Oilseeds Research, Hyderabad using diploid cross compatible five annual Helianthus species and three checks (ARM-243B, DRSF-108, DRSF-113, TAS 82 and Morden) which were evaluated at Oilseeds Research Centre, Akola field in randomized block design with two replications during kharif-2023. In the present investigation days to 50% flowering and days to maturity showed a strong positive correlation (0.9123, 0.9913), plant height was positively correlated with days to maturity (0.6621, 0.6392) , head diameter showed a strong positive correlation with 100 seed weight (0.7180, 0.7512), 100 seed weight had a positive correlation with seed yield per plant (0.3039, 0.2493), leaf length and leaf width were strongly correlated (0.7512, 0.8663), petioles length was positively correlated with 100 seed weight (0.7056, 0.7056), 100 seed weight was positively correlated with volume weight (0.3435, 0.4389) respectively. Genotypic level (G), partial R^2 (0.4167) measured traits 41.67% of the variability in seed yield and phenotypic level (P), partial R^2 (0.1314) indicating that only 13.14% of yield variation can be explained by these traits. Direct effects at genotypic level on seed yield per plant of 100 seed weight (0.5394), plant height (0.3778) and leaf length (0.3744) also showed a high positive direct effect, whereas at phenotypic level 100 seed weight (0.1914) had the highest positive direct effect. Phenotypic and genotypic levels indicating that these attributes were mainly influencing the seed yield in sunflower and strong association of these traits with seed yield per plant could be fruitfully exploited for enhancing the yield potential in sunflower. This suggests that genetic factors play a dominant role in determining yield.

Sunflower (*Helianthus annuus* L.) is one of the most an important oilseed crop in India. It was taken up in view of its various advantages viz., photo and thermo insensitivity, short duration, high yield and better quality of oil. Yield is the most economic character in almost all of the crops. Yield is a complex entity and inheritance of yield depends upon a number of characters which are often polygenic in nature and are highly affected by environmental factors. Knowledge of genetic system controlling yield and its components is useful in understanding the prepotency of the parents and thus help to select parents possessing in-built genetic potential. For efficient selection, programme, interrelationship between yield and its components is inevitable and mutual association of plant characters, which is determined by correlation coefficient and is used to find out the degree (strength), mutual relationship between various plant characters and the component character on which selection can be relied upon the genetic improvement of yield. But information on the relative importance of direct and indirect effects of each component characters towards yield is not provided by such studies. Path coefficient is helpful in partitioning the correlation into direct and indirect effects so that relative contribution of each component character to the yield could be assessed. In other words, path analysis measures the direct and indirect contribution of various independent characters on a dependent character. Therefore, the present investigation

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was undertaken to determine the mutual association among different traits in sunflower and their direct and indirect effects on yield by using path coefficient analysis.

MATERIAL AND METHODS

The experimental material for present investigation consisted of 20 advanced interspecific derivatives developed by Indian Institute of Oilseeds Research, Hyderabad using diploid cross compatible five annual Helianthus species and five checks (ARM-243B, DRSF-108, DRSF-113, TAS 82 and Morden) which were evaluated at Oilseeds Research Centre, Akola field in randomized block design with two replications during kharif-2023. Each pre-bred line was grown in two rows of 4.5 m with 60 x 30 cm spacing between rows and plants, respectively. Fifteen plants were maintained each row. Recommended crop production and protection measures were followed. Observations were recorded from five randomly selected plants in each interspecific derivatives for ten quantitative characters, namely, days to 50% flowering, days to physiological maturity, plant height (cm), head diameter (cm), number of leaves per plant, petiole length (cm), leaf length (cm), leaf width (cm), 100 seed weight (g), volume weight (g/100 ml), and seed yield per plant (g). The genotypic and phenotypic correlations were calculated using the formulae suggested by Fisher and Yates (1967), while the direct and indirect contribution of each character for grain yield was estimated by path co-efficient analysis suggested by Wright (1921).

RESULTS AND DISCUSSION

The genotypic and phenotypic correlations for yield and yield components are presented in Table 1. The results on correlation coefficients revealed that both genotypic and phenotypic correlations followed the same trend but the genotypic correlations were generally higher than the phenotypic correlations indicating that the phenotypic expression of correlations is reduced under the influence of environment. The phenotypic correlations were slightly higher than their genotypic counterparts, which implied that the non-genetic cause inflated the value of genotypic correlation because of the influence of the environmental factors. In the present investigation days to 50% flowering and days to maturity showed a strong positive correlation (0.9123, 0.9913), plant height was positively correlated with days to maturity (0.6621, 0.6392) , head diameter showed a strong positive correlation with 100 seed weight (0.7180, 0.7512), 100 seed weight had a positive correlation with seed yield per plant (0.3039, 0.2493), leaf length and leaf width were strongly correlated (0.7512, 0.8663), petioles length was positively correlated with 100 seed weight (0.7056, 0.7056), 100 seed weight was positively correlated with volume weight (0.3435 , 0.4389), days to maturity had a negative correlation with 100 seed weight (-0.4280, -0.4413), days to 50% flowering also had a negative correlation with 100 seed weight (-0.3380, -0.3446), both at phenotypic and genotypic levels indicating that these attributes were mainly influencing the seed yield in sunflower and strong association of these traits with seed yield per plant could be fruitfully exploited for enhancing the yield potential in sunflower. Thus, selection practiced for the improvement in one character will automatically result in the improvement in the other character even though direct selection for improvement has not been made for the yield character. Genetic correlation between different characters of the plant could be due to linkage, pleiotropy or developmentally induced functional relationships. Similar results exhibiting highly significant and positive correlation between seed yield and other traits as obtained in the present investigation were reported by Venkanna *et al.,* (2014) and Mariyam *et al.,* (2024). Recently, Riaz *et al.,* (2020) reported that plant height and 100 seed weight exhibited a significant positive correlation with achene yield, while Radiæ *et al.,* (2013) found a positive and significant association between seed yield and 100 seed weight. Sincik and Goksoy (2014) reported a significant positive correlation between seed yield and plant height, head diameter and 100 seed weight. Yasin and Singh (2010) reported a significant positive correlation between seed yield and head diameter.

Direct effects from Table 2 and Fig. 1& 2 at genotypic level on seed yield per plant of 100 seed weight (0.5394), plant height (0.3778) and leaf length (0.3744) also showed a high positive direct effect, whereas at phenotypic level 100 seed weight (0.1914) had the highest positive direct effect, but much lower than at the genotypic level. Days to maturity (0.2451) had a positive direct effect,

Table 1: Phenotypic (r_p) and genotypic (r_g) correlation coefficients of different characters in sunflower

Traits	R	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter(cm)	No. of leaves plant^{-1}	Petiole length (cm)	Leaf Length (cm)	Leaf Width (cm)	Volume wt. (g/100 ml)	100 Seed wt (g)
Days to 50% flower	r_p	1.0000									
	r_g	1.0000									
Days to maturity	r_p	0.9123 **	1.0000								
	r_g	0.9913	1.0000								
Plant height (cm)	r_p	0.5883 **	0.6621 **	1.0000							
	r_g	0.6392	0.6621	1.0000							
Head diameter (cm)	r_p	-0.2389	-0.3262 *	-0.1156	1.0000						
	r_g	-0.3208	-0.3526	-0.1249	1.0000						
No. of leaves per	r_p	0.4722 **	0.4267 **	0.4386 **	0.1404	1.0000					
	r_g	0.6180	0.4925	0.5063	0.0493	1.0000					
Petiole length (cm	r_p	-0.2497	-0.3168 *	-0.4011 **	0.3807 **	-0.3260 *	1.0000				
	r_g	-0.3064	-0.4359	-0.5519	0.6555	-0.3271	1.0000				
Leaf Length (cm)	r_p	0.1394	-0.0314	-0.1086	0.5682 **	0.2504	0.4869 **	1.0000			
	r_g	0.0709	-0.0327	-0.1134	0.6553	0.3064	0.7546	1.0000			
Leaf Width (cm)	r_p	0.0967	0.0141	0.0961	0.6599 **	0.2133	0.3437 *	0.7512 **	1.0000		
	r_g	0.0978	0.0172	0.1170	0.6273	0.1195	0.8663	0.9784	1.0000		
Volume wt. (g/100m	r_p	-0.0727	-0.0448	0.1761	0.2023	0.1720	-0.0968	-0.1629	-0.0104	1.0000	
	r_g	-0.0512	-0.0450	0.1771	0.2179	0.2034	-0.1472	-0.1415	-0.0167	1.0000	
100 Seed wt (g)	r_p	-0.3380 *	-0.4280 **	-0.0974	0.7180 **	-0.0875	0.4796 **	0.3535 *	0.4340 **	0.3453 *	1.0000
	r_g	-0.3446	-0.4413	-0.1004	0.7527	-0.1380	0.7056	0.4180	0.4389	0.3477	1.0000
Seed yield (g/plant)	r_p	0.0764	0.0832	0.3479	0.1645	0.1295	-0.2044	-0.0039	0.2597	-0.0040	0.0954
	r_g	0.0777	0.0836	0.3499	0.1737	0.1215	-0.3023	-0.0028	0.3219	-0.0036	0.0967

*Significant at 5% level, **Significant at 1% level

r- Correlation coefficient , r_p-Phenotypic correlation coefficient, r_g-Genotypic correlation coefficient.

Table 2: Genotypic (G) and phenotypic (P) path coefficients among yield attributes

Traits	R	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter(cm)	No. of leaves plant^{-1}	Petiole length (cm)	Leaf Length (cm)	Leaf Width (cm)	Volume wt. (g/100ml)	100 Seed wt (g)
Days to 50% flower	P	0.1179	0.1075	0.0693	-0.0282	0.0557	-0.0294	0.0164	0.0114	-0.0086	-0.0398
	G	-0.6220	-0.6166	-0.3976	0.1995	-0.3844	0.1905	-0.0441	-0.0608	0.0319	0.2144
Days to maturity	P	-0.2663	-0.2919	-0.1933	0.0952	-0.1246	0.0925	0.0092	-0.0041	0.0131	0.1250
	G	0.1558	0.1572	0.1041	-0.0554	0.0774	-0.0685	-0.0051	0.0027	-0.0071	-0.0694
Plant height (cm)	P	0.2222	0.2501	0.3778	-0.0437	0.1657	-0.1515	-0.0410	0.0363	0.0665	-0.0368
	G	0.7615	0.7887	1.1912	-0.1488	0.6031	-0.6574	-0.1351	0.1394	0.2109	-0.1196
Head diameter (cm)	P	-0.0316	-0.0432	-0.0153	0.1324	0.0186	0.0504	0.0752	0.0874	0.0268	0.0951
	G	-0.0938	-0.1032	-0.0366	0.2926	0.0144	0.1918	0.1917	0.1835	0.0637	0.2202
No. of leaves per	P	-0.0135	-0.0122	-0.0126	-0.0040	-0.0286	0.0093	-0.0072	-0.0061	-0.0049	0.0025
	G	-0.0342	-0.0273	-0.0280	-0.0027	-0.0554	0.0181	-0.0170	-0.0066	-0.0113	0.0076
Petiole length (cm	P	0.0498	0.0632	0.0800	-0.0759	0.0650	-0.1994	-0.0971	-0.0685	0.0193	-0.0956
	G	-0.2342	-0.3333	-0.4219	0.5012	-0.2501	0.7645	0.5769	0.6623	-0.1125	0.5394
Leaf Length (cm)	P	-0.0449	0.0101	0.0350	-0.1830	-0.0806	-0.1568	-0.3220	-0.2419	0.0525	-0.1138
	G	0.0265	-0.0123	-0.0425	0.2454	0.1147	0.2825	0.3744	0.3663	-0.0530	0.1565
Leaf Width (cm)	P	0.0415	0.0061	0.0412	0.2830	0.0915	0.1474	0.3221	0.4288	-0.0045	0.1861
	G	-0.0705	-0.0124	-0.0843	-0.4519	-0.0861	-0.6240	-0.7048	-0.7203	0.0120	-0.3162
Volume wt. (g/100m	P	0.0128	0.0079	-0.0310	-0.0356	-0.0302	0.0170	0.0286	0.0018	-0.1758	-0.0607
	G	-0.0028	-0.0025	0.0097	0.0119	0.0111	-0.0081	-0.0077	-0.0009	0.0547	0.0190
100 Seed wt (g)	P	-0.0114	-0.0144	-0.0033	0.0241	-0.0029	0.0161	0.0119	0.0146	0.0116	0.0336
	G	0.1914	0.2451	0.0558	-0.4180	0.0766	-0.3918	-0.2321	-0.2437	-0.1931	-0.5553
Seed yield (g/plant)	P	0.0764	0.0832	0.3479	0.1645	0.1295	-0.2044	-0.0039	0.2597	-0.0040	0.0954
	G	0.0777	0.0836	0.3499	0.1737	0.1215	-0.3023	-0.0028	0.3219	-0.0036	0.0967
Partial R2	P	0.0090	-0.0243	0.1314	0.0218	-0.0037	0.0408	0.0012	0.1114	0.0007	0.0032
Partial R2	G	-0.0483	0.0131	0.4167	0.0508	-0.0067	-0.2311	-0.0011	-0.2319	-0.0002	-0.0537

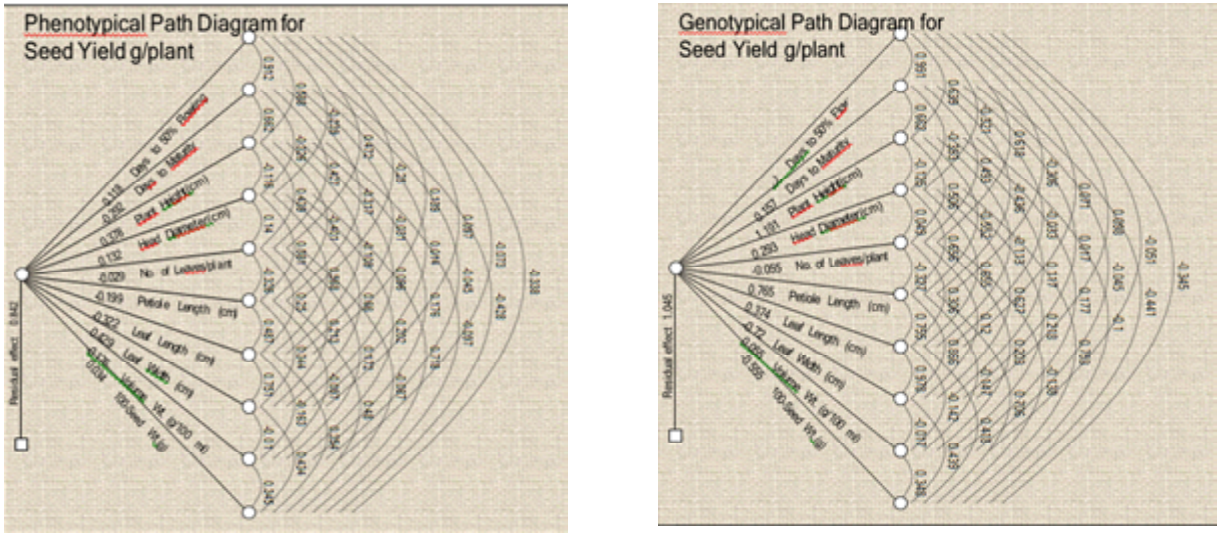

Fig. 1: Genotypic and phenotypic path diagram showing direct and indirect effects of yield components on seed yield at phenotypic and genotypic level

meaning later-maturing plants tend to have slightly higher yields. It indicated that the direct selection for these characters will be rewarding to obtain the high yielding genotypes as revealed by their close association with seed yield per plant. These results are in consonance with the earlier reports of Kholghi *et al*., (2011). Plant height (0.1314) had a moderate positive direct effect on yield.

Indirect effects on seed yield at the genotypic level leaf width (0.7208, indirect through other traits) showed a high indirect positive effect via leaf length and head diameter, suggesting that broader leaves contribute indirectly to yield. Head diameter (0.4519) contributed positively but indirectly, indicating its role in accommodating more seeds. Petioles length (-0.6240) had a strong negative indirect effect, meaning longer petioles might reduce yield. At the phenotypic level leaf length (0.7048, indirect via plant height and leaf width) played an important indirect role in yield formation. Days to 50% flowering (-0.1444) had a small negative indirect effect, meaning early flowering may slightly reduce yield. At the genotypic level (G), partial R^2 (0.4167) meaning that the measured traits explain 41.67% of the variability in seed yield. At the phenotypic level (P), partial R^2 (0.1314) indicating that only 13.14% of yield variation can be explained by these traits at the phenotypic level. This suggests that genetic factors (rather than environmental effects) play a dominant role in determining yield. Similar finding also reported by Tilak *et al*., (2016) and Pandya *et al*., (2015). However, the present findings do not support the conclusion of Naik and Ghodke (2021), who reported positive direct effect of days to 50% flowering with seed yield. In general, character association and path coefficient analysis carried out in this study suggest that 100 seed weight, followed by number of seeds per head and volume weight influence the seed yield more than any of the characters taken for study. Hence, more emphasis would be given to these characters during selection to improve the seed yield. Also, the narrow differences between a genotypic and phenotypic values indicates that the environment does not play a major role in the relationship between traits. Hence, selection based on phenotypic performance of different traits will be fairly effective.

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Genetic variability, heritability, correlation and path analysis studies in Sunflower lines (*Helianthus annuus* L.)

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ABSTRACT

The experimental material for present investigation consisted of 50 germplasm lines from Indian Institute of Oilseeds Research, Hyderabad with three checks (DRSF-108, DRSF-113, and Phule Bhaskar) which were maintained and evaluated at Oilseeds Research Centre, Akola field in randomized block design with two replications during kharif-2023. Maximum GCV recorded was 37.00 per cent for 100 seed weight and lowest of 4.32 per cent for days to maturity. Genetic advance observed highest for plant height with 59.49 per cent and lowest for 100 seed weight with 3.39 per cent and genetic advance over mean was more (75.97%) for 100 seed yield. 100 seed weight (g) recorded the highest heritability (99.70%) and genetic advance (75.97%), making it the most genetically stable trait. This suggests that selection for this trait will result in significant genetic gain. Days to 50% flowering and days to maturity genotypic correlation (1.0739) is very high, indicating strong genetic linkage. Phenotypic correlation (0.6193) is also significant suggesting that early flowering plants tend to mature early. Genotypic direct effect on seed yield (0.2937 for 100 seed weight) is the highest among all traits, confirming that seed weight is a primary determinant of yield. Phenotypic direct effect on seed yield (0.1374 for 100 seed weight) is also positive, reinforcing its significance in sunflower breeding. High heritability and strong direct effect make it the most important selection criterion. Breeding programs should emphasize seed density and size improvement.

Sunflower, emerged as an important oilseed crop, a rich source of edible oil (40-52%) having anti-cholesterol properties due to the presence of polyunsaturated fatty acids (55- 65% Linoleic acid and 20-30% Oleic acid), which are known to reduce the risk of coronary diseases. In sunflower, seed yield and oil content are complex traits which are affected by several component traits and environmental factors. To understanding the traits interaction among themselves and with the environment is very essential in planning successful crop improvement program. Information on variability and heritability is useful to formulate selection criteria for improvement of seed yield and its component traits. Heritability estimates along with genetic advance are normally more helpful in predicting the gain under selection than heritability estimates alone. So, taking all these aspects into consideration, the present study was conducted to evaluate the extent of genetic variability, heritability and genetic advance over mean for seed yield and its component traits in sunflower.

Correlation study provides an insight on the nature and extent of association between any two pairs of metric characters. From this it would be possible to bring about genetic enhancement in commercially important character like seed yield through indirect selection of component traits. Unlike the correlation coefficient values which measures the extent of relationship, path coefficient splits the correlation coefficient into measures of direct and indirect effects and estimates the direct and indirect contribution of various component traits towards yield. Hence, the correlation coefficient represents the sum total effects (direct or indirect) of all traits to which it is correlated either positively or negatively and hence selection based on this value alone will be time consuming unless the direct effect is very high and operate in the same direction. Hence, the study of direct and indirect effects through the path analysis has gained much importance. It also helps to improve different characters simultaneously. In this direction, a study on correlation and path analysis was conducted for yield and yield component traits in sunflower.

MATERIAL AND METHODS

The experimental material for present investigation consisted of 50 germplasm lines from Indian Institute of Oilseeds Research, Hyderabad with three checks (DRSF-108, DRSF-113, and Phule Bhaskar) which were maintained and evaluated at Oilseeds Research

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Centre, Akola field in randomized block design with two replications during kharif-2023. Each line was grown in two rows of 4.5 m with 60 x 30 cm spacing between rows and plants, respectively. Fifteen plants were maintained each row. Recommended crop production and protection measures were followed. Observations were recorded from five randomly selected plants in each germplasm line for six quantitative characters, namely, days to 50% flowering, days to physiological maturity, plant height (cm), head diameter (cm), 100 seed weight (g), and seed yield per plant (g). Mean performance of the genotypes were calculated and the genotypic coefficient (GCV) and phenotypic coefficient of variation (PCV) was estimated by using the formula given by Burton (1952). The estimates of PCV and GCV were classified as low (0-10%), moderate (10-20%) and high (>20%) according to Sivasubramanian and Madhavamenon (1973). Heritability in broad sense (h^2 b) was estimated according to the formula suggested by (Johnson *et al.,* 1955) and (Hanson *et al.,* 1956). Estimation of genetic advance was done following the formula given by Johnson *et al.,* (1955) and Allard (1960). The genotypic and phenotypic correlations were calculated using the formulae suggested by Fisher and Yates (1967), while the direct and indirect contribution of each character for grain yield was estimated by path coefficient analysis suggested by Wright (1921).

RESULTS AND DISCUSSION

Genetic variability, heritability and genetic advance

The results pertaining to genetic variability component parameters viz., range, mean, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), broad sense heritability (h_{2bs}) and genetic advance as per cent of mean (GAM) for all the characters are presented in Table 1. From the Table 1 it is clear that the magnitude of genotypic coefficient of variation was less than phenotypic coefficient of variation for all the trait studied. Maximum GCV recorded was 37.00 per cent for 100 seed weight and lowest of 4.32 percent for days to maturity. Due to masking influence of environment upon characters concerned, values of genetic advance exhibited high fluctuations. Therefore, to attain relative comparison of the characters in relation to environment, genetic advance as percentage of mean (GAM) was calculated to predict the genetic gain. Genetic advance observed highest for plant height with 59.49 per cent and lowest for 100 seed weight with 3.39 percent and genetic advance over mean was more (75.97%) for 100 seed yield. Similar results were reported by Khandelwal *et al.,*. (2014) and Gahukar and Fatak (2021).

Seed yield (g/plant) showed high heritability (94.60%) and high genetic advance as a percentage of mean (55.74%), indicating that this trait is largely controlled by genetic factors. Selection for seed yield can be effective in sunflower breeding programs. Days to 50% flowering and days to maturity exhibited moderate heritability (66.30% and 75.90%) and low genetic advance (7.63% and 6.75%), suggesting that environmental factors influence these traits. Plant height (cm) and head diameter (cm) had high heritability (99.80% and 89.00%) and high genetic advance (38.06% and 50.89%), indicating strong genetic control. These traits can be effectively improved through

Table 1 : Mean, range, coefficient of variation, heritability and genetic advance as per cent of mean for different traits in sunflower

Characters	Mean	Range	Coefficient of Variation		h² (Broad Sense)	Genetic Advance	Genetic Advance Mean
			GCV (%)	PCV (%)			
Seed Yield (g/ plant)	30.8	10.2-48.6	27.82	28.61	94.60	17.16	55.74
Days to 50% flowering	66	52-75	4.55	5.58	66.30	5.03	7.63
Days to maturity	103	80-110	3.76	4.32	75.90	6.96	6.75
Plant height (cm)	156.3	100.2-220.5	18.49	18.51	99.80	59.49	38.06
Head diameter (cm)	13.0	6.9-23.0	26.13	27.64	89.40	6.62	50.89
100 seed wt.(g)	4.4	1.8-9.0	36.94	37.00	99.70	3.39	75.97

Table 2: Phenotypic (r_p) and genotypic (r_g) correlation coefficients of different characters in sunflower

Traits	R	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 Seed wt (g)
Days to 50% flower	r_p	1.0000				
	r_g	1.0000				
Days to maturity	r_p	0.6193 **	1.0000			
	r_g	1.0739	1.0000			
Plant height (cm)	r_p	0.4056 **	0.3303 **	1.0000		
	r_g	0.4928	0.3846	1.0000		
Head diameter(cm)	r_p	0.1421	0.1778	0.5813 **	1.0000	
	r_g	0.1413	0.1646	0.6210	1.0000	
100 Seed wt (g)	r_p	0.2489 *	0.3492 **	0.5698 **	0.5856 **	1.0000
	r_g	0.3271		0.3806	0.5718	0.6213
1.0000						
Seed yield (g/plant)	r_p	0.0078	0.0116	0.1222	-0.0317	0.1268
	r_g	-0.0173	0.0417	0.1282	-0.0403	0.1362

*Significant at 5% level, **Significant at 1%level r- Correlation coefficient ,

r_p -Phenotypic correlation coefficient, r_g -Genotypic correlation coefficient.

Table 3: Genotypic (G) and phenotypic (P) path coefficients among yield attributes

Traits	R	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 Seed wt. (g)
Days to 50% flower	P	-0.0587	-0.0363	-0.0238	-0.0083	-0.0146
	G	0.3812	0.4094	0.1879	0.0539	0.1247
Days to maturity	P	-0.0231	-0.0372	-0.0123	-0.0066	-0.0130
	G	-0.5202	-0.4844	-0.1863	-0.0797	-0.1844
Plant height (cm)	P	0.0772	0.0628	0.1902	0.1106	0.1084
	G	0.0650	0.0507	0.1319	0.0819	0.0754
Head diameter (cm)	P	-0.0333	-0.0417	-0.1365	-0.2347	-0.1374
	G	-0.0394	-0.0459	-0.1731	-0.2788	-0.1732
100 Seed wt. (g)	P	0.0457	0.0641	0.1045	0.1074	0.1835
	G	0.0961	0.1118	0.1679	0.1825	0.2937
Seed yield (g/plant)	P	0.0078	0.0116	0.1222	-0.0317	0.1268
	G	-0.0173	0.0417	0.1282	-0.0403	0.1362
Partial R2	P	-0.0005	-0.0004	0.0233	0.0074	0.0233
Partial R2	G	-0.0066	-0.0202	0.0169	0.0112	0.0400

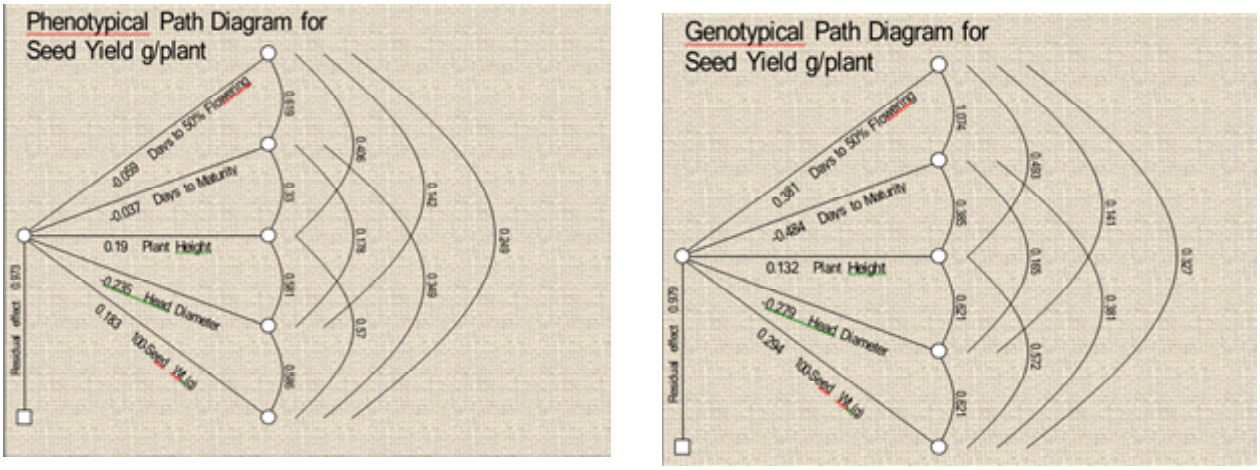

Fig 1: Genotypic and phenotypic path diagram showing direct and indirect effects of yield components on seed yield at phenotypic and genotypic level

selection. 100 seed weight (g) recorded the highest heritability (99.70%) and genetic advance (75.97%), making it the most genetically stable trait. This suggests that selection for this trait will result in significant genetic gain. Similar results were reported by Neelima *et al.,* (2016). and Harshavardan *et al.,* (2021).

Genotypic and phenotypic correlation

The Table 2 presents phenotypic (rš) and genotypic (r_g) correlation coefficients among different sunflower traits. These correlations help in understanding how traits influence each other at both the genetic and phenotypic levels. Days to 50% flowering and days to maturity genotypic correlation (1.0739) is very high, indicating strong genetic linkage. Phenotypic correlation (0.6193) is also significant suggesting that early flowering plants tend to mature early. Plant height and head diameter genotypic correlation (0.6210) is high, implying that taller plants tend to have larger heads whereas phenotypic correlation (0.5813) is also significant. 100 seed weight and head diameter genotypic correlation (0.6213) is moderately high, suggesting that larger head diameter is associated with heavier seeds. 100 seed weight and plant height genotypic correlation (0.5718) and phenotypic correlation (0.5698) indicate a strong positive association, meaning taller plants tend to produce heavier seeds. Similar results also recorded by Hladni *et al.,* (2006), Rauf, (2019), and Harshvardhan *et al.,* (2021). Seed yield correlations are weak observed between with other traits at both genotypic and phenotypic levels, suggesting that seed yield is influenced by multiple complex factors rather than a single trait. Strong genetic correlations ($r_g > 0.6$) suggest that selection for early flowering, plant height, head diameter, and 100 seed weight may help improve sunflower yield indirectly. Highly significant phenotypic correlations (rš) indicate that these traits are visibly linked in plant populations, making selection feasible.

Path analysis

The Table 3 and fig. 1 presents genotypic direct effect on seed yield (0.2937 for 100 seed weight) is the highest among all traits, confirming that seed weight is a primary determinant of yield. Phenotypic direct effect on seed yield (0.1374 for 100 seed weight) is also positive, reinforcing its significance in sunflower breeding (Seiler, 2010). Selecting for higher seed weight will directly improve yield and should be prioritized in breeding programs (Miller & Seiler, 2003). Plant height shows a positive genotypic direct effect (0.1879) and phenotypic effect (0.1902) on seed yield, indicating its contribution through biomass and better resource allocation (Kaya & Evci, 2001). Head diameter has a moderate genotypic effect (0.0539) but negative phenotypic effect (-0.2347), suggesting that larger heads enhance yield genetically, but environmental instability may reduce effectiveness (Hladni *et al.,* 2006). Days to maturity has a strong negative genotypic direct effect (-0.5202), implying that late-maturing varieties are less productive due to inefficient resource use (Sadras *et al.,* 1993). Seed yield is highly correlated with seed weight (0.6213), plant height (0.5718), and head diameter (0.5856)

at the genotypic level, confirming these as major yield components.

Selecting taller plants with optimal head diameter and heavier seeds will significantly enhance seed yield (Rauf 2019). High heritability and strong direct effect make it the most important selection criterion. Breeding programs should emphasize seed density and size improvement. Taller plants contribute positively to yield but should be balanced to prevent lodging. Hybridization should focus on moderate height varieties with strong stems.

Negative direct effect of late maturity (-0.5202) indicates that earlier-maturing hybrids are more productive. Selection should focus on high-yielding early-maturing genotypes. While head diameter is genetically associated with yield, its phenotypic effect varies. Multi-environment testing is needed for stable expression in different conditions. Seed weight is the strongest direct contributor to yield, followed by plant height. Early-maturing hybrids are superior to late-maturing varieties for higher yield. Taller plants with moderate head diameter are ideal for maximizing yield potential. Selection should be multi-trait based rather than focusing on a single parameter.

This study confirms that seed weight, plant height, and head diameter are key yield determinants in sunflower breeding. Early-maturing hybrids with improved seed weight and balanced plant height should be prioritized to achieve higher yield stability and genetic advancement.

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Combining Ability Studies for Earliness, Yield and Yield Components in Pigeonpea (*Cajanus cajan* (L.) Millsp)

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ABSTRACT

The experiment was conducted at Seed Technology Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. with eleven males (ICPL 332 WR, AL 2255, AL 882, AL 2207, IPAE 20-11, IPAE 19-04, IPAE 20-5, IPAE 20-10, IPAE 19-21, ICPL 88039, ICPL 151) were crossed with three females (PDKV Ashlesha, AKTE 12-04, BSMR 736) and thirty three hybrids were developed following line x tester mating design. These 33 hybrids along with their parental lines and checks viz. IPA 15-06, UPAS 120, PKV Tara evaluated during kharif 2023-24. The mean squares of parents were significant for all the nine yield and yield contributing characters. The mean squares of crosses effects were significant for all the characters. This indicated the presence of significant differences between males and females for these traits. The estimates of GCA effects revealed that BSMR 736, ICPL 151, ICPL 332 WR and IPAE 20-11 were the good general combiners for grain yield per plant and most of the yield contributing characters. The parents AL 2255, AL 2207, AL 882, IPAE 20-5 and IPAE 19-21 have registered significant negative GCA effects for days to 50% flowering and days to maturity. In general, good general combiners for grain yield also had good or average combining ability for one or more yield components. In most of the parents high GCA effects were associated with high *per se* mean for yield and yield components. However, based on *per se* performance and GCA effects, among the males, AL 2255, AL 882, AL 2207 and ICPL 88039 were found to be the best for earliness, while ICPL 151 and ICPL 332 WR was found promising for seed yield and other yield contributing characters except no of primary branches. Among the female, BSMR 736 emerged as the best for no. pods per plant and seed yield per plant, which can be utilized in the breeding programmes. Based on SCA effects and heterosis, the hybrids *viz*., AKTE 12-04 x ICPL 151, AKTE 12-04 x IPAE 19-21, BSMR 736 x AL 2207, PDKV Ashlesha x AL 882, PDKV Ashlesha x IPAE 20-10,BSMR 736 x IPAE 20-11 were identified as the best specific combiners for yield and yield attributing traits, which can be further utilized for hybrid breeding programme. Based on SCA effects and heterosis, the hybrids *viz*., PDKV Ashlesha x AL 2255, BSMR 736 x AL 882, PDKV Ashlesha x ICPL 88039, AKTE 12-04 x AL 882, , AKTE 12-04 x IPAE 19-21 and BSMR 736 x IPAE 20-5 were identified as the best specific combiners for earliness.

Pigeonpea [*Cajanus cajan* (L.) Millsp.], also known as red gram, tur or arhar, is a vital grain legume crop cultivated in tropical and subtropical regions worldwide. As a member of the Fabaceae family, pigeonpea plays a crucial role in sustainable agriculture and food security, particularly in developing countries. India is considered the primary center of origin for pigeonpea due to its vast natural genetic variability in local germplasm and the presence of wild relatives. Pigeonpea exhibits diverse maturity durations, ranging from 90 to 300 days, which allows it to fit into a wide array of cropping systems. This variation in maturity has led to the classification of pigeonpea varieties into three main groups: early maturing (90-150 days), medium maturing (150-180 days), and late maturing (180-300 days). Combining ability studies are essential for identifying parental combinations that can maximize heterosis effects. General Combining Ability (GCA) and Specific Combining Ability (SCA) analyses provide insights into the genetic control of important traits. This information is crucial for improving complex traits like yield, disease resistance and abiotic stress tolerance, which are often governed by multiple genes. Combining ability studies help identify superior parents (those with high GCA) and promising cross combinations (those with high SCA). This information is invaluable for designing efficient breeding programs and allocating resources effectively..

The relative importance of GCA and SCA effects provides insights into the predominant type of gene action

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(additive vs. non-additive) controlling trait expression. This knowledge guides breeders in choosing appropriate selection methods and breeding strategies. GCA and SCA effects can be used to predict the performance of untested hybrids, potentially reducing the need for extensive field testing of all possible cross combinations.

The exploitation of heterosis depends much on general and specific combining ability effects. Combining ability studies provide useful information for evaluating parental and their cross combinations which helps in selection of parents in terms of performance of hybrids and explain the nature and extent of different types of gene actions which play role in expressing the quantitative traits.

MATERIAL AND METHODS

The experiment was conducted at Seed Technology Research Unit, Dr. Panjabroa Deshmukh Krishi Vidyapeeth, Akola. with eleven males (ICPL 332 WR, AL 2255, AL 882, AL 2207, IPAE 20-11, IPAE 19-04, IPAE 20-5, IPAE 20-10, IPAE 19-21, ICPL 88039, ICPL 151) were crossed with three females (PDKV Ashlesha, AKTE 12-04, BSMR 736) and thirty three hybrids were developed following line x tester mating design. These 33 hybrids along with their parental lines and checks viz. IPA 15-06, UPAS 120, PKV Tara evaluated during kharif 2023-24. Observations were recorded on different quantitative characters and genotypes were analysed as per line x tester mating design, while mean data on genotypes (11 males, 3 females, 33 hybrids, 3 checks) was used for estimation of heterosis. Analysis of variance was carried out as per standard method (Panse and Sukhatme, 1967) for all characters under study. The combining ability analysis were computed as per the methods suggested by Kempthorne (1957)

RESULT AND DISCUSSION

Combining ability studies helps the breeder in selecting the parents and breeding methods to be employed to improve a particular trait, as it provides the information on the genetic nature of the traits. General combing ability (GCA) is attributed to additive (fixable) gene action, while specific combing ability (SCA) is attributed primarily due to dominance, over dominance and epistatic effects of genes (non-additive). The non-additive gene action is mostly non-fixable, but often brings about in phenotypes that are not attainable under normal additive gene action. The ratio of GCA to SCA variance provides an estimate of the predominance of additive gene effects or the non-additive gene effects.

Analysis of variance

The analysis of variance for combining ability was carried out for 9 characters and mean sum of squares are presented in Table 1. The effects of hybrids was partitioned into lines, testers and their interactions. The males were found to be significant for days to 50% flowering, days to maturity, 100 seed weight and pod length. Among females, the differences were non-significant for all the characters. The interaction effects (lines x testers) were found to be significant for all the characters.

Estimates of the relative contribution of GCA and SCA in a population are of interest to plant breeders, as selection of breeding methods most appropriate for specific objectives may differ appreciably based on type of gene action. The estimates of components of variance and their ratio ($ó^2GCA$ / $ó^2SCA$) indicated the preponderance of non-additive gene action for all the traits in the study. General combining ability effects of the parents in the Table 2 and specific combining ability effects of hybrids are presented in Table 3 for parents and hybrids, respectively.

General Combining Ability

General combining ability (GCA) effect for parents is presented in Table (2) Males for days to 50% flowering recorded AL882 (-10.227), ICPL 88039 (-9.227), AL 2255 (-8.727), IPAE 19-21 (-7.394) and IPAE 20-5 (-5.394) had highly significant negative GCA effect which is related to earliness. The female PDKV Ashlesha (-2.061) recorded significant negative GCA effects for this trait. The males ICPL 332 WR (19.61), IPAE 20-10 (9.27), IPAE 20-11 (8.939), ICPL 151 (8.27) and IPAE 19-04 (5.106) showed positive significant GCA effects. For days to maturity in AL 2255 (-11.23), AL 2207 (-11.061), AL 882 (-10.39), IPAE 19-21(-9.06) and IPAE 20-5 (-6.89) showed significant negative GCA effect indicating their use as general combiners in

Table 1 : ANOVA for Line x Tester

Sources of variation	D.f.	Mean sum of squares								
		Plant height (cm)	Days to 50% Flowering	Days to maturity	100 seed weight(g)	No. of pods plant^{-1}	No. of seeds pod^{-1}	No. of primary branches plant^{-1}	Pod length (cm)	Grain yield plant^{-1} (g)
Replications	1	123.63	0.52	1.53	0.06	1.72	0.02*	1.06	0.04	2.43
Parents	13	908.62**	509.72**	642.68**	3.22**	3119.73**	0.19**	10.44**	0.66**	413.10**
Crosses	32	367.24**	245.59**	218.01**	2.97**	4059.97**	0.22**	8.43**	0.60**	834.53**
Parents x Crosses	1	8446.94**	252.28**	394.67**	1.54*	32692.84**	0.79**	91.19**	0.0005	5032.87**
Males	10	493.79	659.44**	668.25**	6.28**	1771.18	0.10	5.67	1.40**	933.48
Females	2	66.08	70.10	8.318	2.12	4549.95	0.15	0.20	0.25	641.24
Females x Males	20	334.09**	56.20**	13.87**	1.407**	5155.40**	0.29**	10.63**	0.23**	804.39**
Error	46	32.82	2.26	5.29	0.37	69.56	0.005	1.56	0.017	45.61

*- Significant at 5% level of significance ** - Significant at 1% level of significance

Table 2: General combining ability of parents in pigeonpea.

S.N.	Female Parents	Plant height (cm)	Days to 50% Flowering	Days to maturity	100 seed weight(g)	No. of pods plant^{-1}	No. of seeds pod^{-1}	No. of primary branches plant^{-1}	Pod length (cm)	Grain yield plant^{-1} (g)
1	PDKV Ashlesha	0.218	-2.061**	-0.652	0.182	5.227	-0.079	0.106	-0.064*	0.69
2	AKTE 12-04	1.614	0.985**	-0.015	-0.359**	-16.264	0.085	-0.03	0.123**	-5.71**
3	BSMR 736	-1.832	1.076**	0.667	0.177	11.036	-0.006	-0.076	-0.059*	5.021**
	SE (d)	1.221	0.321	0.508	0.130	1.778	0.014	0.266	0.028	1.440
	CD 5%	2.459	0.645	1.022	0.262	3.579	0.029	1.993	2.013	2.898
	CD 1%	3.281	0.861	1.364	0.349	4.778	0.039	2.647	2.687	3.868

*- Significant at 5% level of significance ** - Significant at 1% level of significance

Tabel 2 Contd….

S. N.	Male Parents	Plant height (cm)	Days to 50% flowering	Days to maturity	100 seed wt. (g)	No. of pods plant^{-1}	No. of seeds pod^{-1}	No. of primary branches plant^{-1}	Pod length (cm)	Grain yield Plant^{-1} (g)
1	ICPL 332 WR	6.802**	19.606**	19.439**	1.65**	25.465**	0.106**	-1.273**	-0.198**	25.182**
2	AL 2255	-16.332**	-8.727**	-11.227**	-0.285	-25.802**	-0.066*	-1.106**	0.234**	-10.928**
3	AL 882	-15.415**	-10.227**	-10.394**	-0.79**	-16.552**	0.004	-0.106	-0.028	-13.447**
4	AL 2207	2.635	-10.277**	-11.061**	-0.365	21.332**	0.099**	0.277*	-0.086	0.992
5	IPAE 20-11	-2.865	8.939**	9.273**	0.816**	7.782*	0.034	1.394**	-0.429**	10.932**
6	IPAE 19-04	6.318**	5.106**	5.106**	-0.139	20.348**	-0.204**	-0.606*	-0.161**	5.54
7	IPAE 20-5	-3.832	-5.394**	-6.894**	-1.207**	0.048	0.014	-0.939*	0.046	-11.145**
8	IPAE 20-10	-0.565	9.273**	7.439**	0.488	2.498	-0.232**	1.561**	-0.349**	0.26
9	IPAE 19-21	9.968**	-7.394**	-9.061**	-1.072**	-12.418**	-0.061*	0.894*	-0.369**	-13.568**
10	ICPL 88039	3.935	-9.227**	1.894**	-0.767**	14.168**	0.119**	0.227*	0.012	-5.357
11	ICPL 151	9.352**	8.273**	9.273**	1.67**	-8.535*	0.186**	-0.273*	1.327**	11.542**
	SE (d)	2.339	0.614	0.972	0.249	3.405	0.027	0.884	0.054	2.757
	CD 5%	4.708	1.235	1.957	0.502	6.854	0.556	1.018	0.109	5.550
	CD 1%	6.284	1.649	2.613	0.670	9.150	0.074	1.351	0.145	7.408

* -Significant at 5% level of significance ** -Significant at 1% level of significance

getting early maturing types, hence they can be utilized as good donor sources in breeding for earliness. None of the female recorded significant GCA effects. Results was in confirmity with the results reported by Pandey (1999), Jayamala and Rathnaswamy (2000),

For plant height recorded in IPAE 19-21 (9.97), ICPL 151 (9.35), ICPL 332 WR (6.80) and IPAE 19-04 (6.32) exhibited significant positive GCA effect while maximum significant negative GCA effect is exhibited by AL 2255 (-16.33). None of the female parents recorded significant GCA effect for this trait, indicating there is limited variability among females for improving this character. Among the male parents, number of primary branches per plant IPAE 20-10 (1.57) expressed significant positive GCA effect, while ICPL 332 WR (-1.273) recorded significant negative GCA effect. None of the female parents recorded significant GCA effect for this trait, indicating there is limited variability for improving this character (Table 2). The females number of pods per plant in BSMR 736 (11.04) and PDKV Ashlesha (5.23) manifested significant positive GCA effect, whereas, AKTE 12-04 (-16.26) recorded significant negative GCA effect. Among males, ICPL332 WR (25.47), AL 2207 (21.33), IPAE 19-04 (20.35), ICPL 88039 (14.17) and IPAE 20-11 (7.78) exhibited significant positive GCA effect. The AL 2255 (-25.80) recorded the highest significant negative GCA effect followed by AL 882 (-16.55).

For 100 seed weight of the three females, PDKV Ashlesha (0.18) and BSMR 736 (0.17) showed significant positive and AKTE 12-04 (-0.359) recorded significant negative GCA effects. Among males, highest significant positive GCA effect was observed for ICPL 151 (1.67) followed by ICPL 332 WR (1.67) and IPAE 20-11 (0.816). While IPAE 20-5 (-1.21), IPAE 19-21 (-1.07), AL 882 (-0.79) and ICPL 88039 (-0.77) males recorded significant negative GCA effect. For number of seeds per pod, AKTE 12-04 (0.085) recorded highest significant positive GCA effect among the females and PDKV Ashlesha (-0.079) recorded significant negative GCA effect. Out of eleven males, ICPL 151 (0.19), ICPL 88039 (0.12), ICPL 332 WR (0.11) and AL 2207 (0.09) recorded significant positive GCA effect while IPAE 20-10 (-0.23), IPAE 19-04 (-0.20), AL 2255 (-0.07) and IPAE 19-21 (-0.06) recorded significant negative GCA effect for the trait 100 seed weight.

Among the females, grain yield per plant recorded in BSMR 736 (5.02) manifested significant positive GCA effect, whereas female AKTE 12-04 (-5.71) exhibited highest significant negative GCA effect. Among testers, ICPL332 WR (25.18), ICPL151 (11.54) and IPAE 20-11 (10.93) showed significant positive GCA effect while testers IPAE 19-21 (-13.57), AL 882 (-13.45), IPAE 20-5 (-11.15) and AL 2255 (-10.93) had significant negative GCA effect.

For seed yield per plant, the female BSMR 736 and the tester ICPL 332 WR were found to be good general combiners for their utility in breeding programmes in the improvement of seed yield. Mean performance of parents revealed that the no single genotype was superior in respect of all the traits studied. However, based on per se performance and GCA effects, among the males, AL 2255, AL 882, AL 2207 and ICPL 88039 were found to be the best for earliness, while ICPL 151 and ICPL 332 WR was found promising for seed yield and other yield contributing characters except no of primary branches. Among the female, BSMR 736 emerged as the best for no. pods per plant and seed yield per plant, which can be utilized in the breeding programmes.

Specific combining ability

Ten hybrids *viz*., BSMR 736 x ICPL 151 (-7.41), PDKV Ashlesha x ICPL 332 WR (-7.11), BSMR 736 x IPAE 20-11 (-5.58), PDKV Ashlesha x IPAE 20-10 (-5.27), AKTE 12-04 x AL 882 (-4.82), AKTE 12-04 x IPAE 20-10 (-3.82), BSMR 736 x IPAE 20-5 (-3.74), BSMR 736 x AL 882 (-2.91), AKTE 12-04 x IPAE 19-04 (-2.61) and BSMR 736 x AL 2207 (-2.41) recorded negative and highly significant SCA effects indicating the possibility of improvement for early flowering. On contrary, the hybrids *viz*., BSMR 736 x IPAE 20-10 (9.09), AKTE 12-04 x IPAE 20-11(7.52), BSMR 736 x ICPL 332 WR (6.76), PDKV Ashlesha x AL 882 (4.73), PDKV Ashlesha x ICPL 151(4.68), AKTE 12-04 x ICPL 151 (4.68), PDKV Ashlesha x AL 2207 (4.23),BSMR 736 x IPAE 19-04 (4.26), BSMR 736 x AL 2255 (4.09) and PDKV Ashlesha x IPAE 19-21 (2.89) registered positive and highly significant SCA effects, indicating that these hybrids late in flowering. (Table 3). Non-additive gene action recorded for days to 50% flowering in the present investigation was in confirmity with the results reported by Pandey (1999), Jayamala and Rathnaswamy (2000), and Patel and Tikka (2015).

Table 3: Specific combining ability of crosses

S.N.	Crosses	Plant height (cm)	Days to 50% flowering	Days to maturity	100 seed wt. (g)	No. of pods plant^{-1}	No. of seeds pod^{-1}	No.of primary branches plant^{-1}	Pod length (cm)	Grain yield Plant^{-1} (g)
01	PDKV Ashlesha X ICPL 332 WR	-3.152	-7.106**	0.075	-0.117	20.039**	-0.594**	1.727	-0.204*	-1.253
02	PDKV Ashlesha X AL 2255	-2.068	0.727	-3.75*	0.939*	-9.194	0.033	-0.439	0.039	3.942
03	PDKV Ashlesha X AL 882	20.815**	4.727**	8.40**	-0.335	78.506**	0.113*	0.561	0.066	23.9**
04	PDKA Ashlesha X AL 2207	-5.385	4.227**	-0.257	0.277	-45.927**	0.198**	-0.773	-0.096	-10.623*
05	PDKA Ashlesha X IPAE 20-11	-3.885	-1.939	0.909	0.352	-5.977	-0.097*	1.061	0.027	-0.153
06	PDKA Ashlesha X IPAE 19-04	-1.918	-2.606*	1.575	-0.525	-0.344	0.756**	0.561	0.349**	4.499
07	PDKA Ashlesha X IPAE 20-5	9.632*	1.894	2.575	0.081	58.006**	-0.037	0.394	0.022	21.329**
08	PDKA Ashlesha X IPAE 20-10	-4.185	-5.273**	-2.757	1.458**	-23.894**	0.019	-1.606	-0.078	1.504
09	PDKA Ashlesha X IPAE 19-21	-0.318	2.894**	0.242	-0.885*	-36.677**	0.143**	-0.939	0.342**	-14.498**
10	PDKA Ashlesha X ICPL 88039	-5.035	-0.273	-5.424**	0.005	-15.827*	-0.287**	0.727	-0.284**	-7.41
11	PDKA Ashlesha X ICPL 151	-4.502	4.682**	-1.590	-1.249**	-18.711**	-0.244**	-1.273	-0.184	-21.238**
12	AKTE 12-04 X ICPL 332 WR	5.453	0.348	-1.833	-0.198	-28.27**	0.681**	0.364	0.593**	-4.653
13	AKTE 12-04 X AL 2255	-24.714**	-4.818**	0.833	-0.584	-34.903**	0.023	-2.303*	0.292**	-17.233**
14	AKTE 12-04 X AL 882	9.27*	-1.818	-4.00*	0.214	-18.603**	-0.002	3.697**	-0.182	-7.025**
15	AKTE 12-04 X AL 2207	-2.58	-1.818	1.333	-0.254	-46.636**	0.053	-2.136**	-0.108	-14.548*
16	AKTE 12-04 X IPAE 20-11	2.62	7.515**	0.50	-0.889*	0.314	-0.502**	0.197	0.225**	-14.858*
17	AKTE 12-04 X IPAE 19-04	2.036	-1.652	-0.833	-0.375	-0.903	-0.423**	2.197*	-0.298**	-12.676*
18	AKTE 12-04 X IPAE 20-5	1.586	1.848	1.166	0.598	-46.453**	0.173**	0.53	-0.155	-12.016*
19	AKTE 12-04 X IPAE 20-10	0.62	-3.818**	-1.166	-0.502	27.597**	0.045	-0.47	0.295**	6.309

*-Significant at 5% level of significance, ** -Significant at 1% level of significance

Table 3 Contd……

S.N.	Crosses	Plant height (cm)	Days to 50% flowering	Days to maturity	100 seed wt. (g)	No. of pods plant^{-1}	No. of seeds pod^{-1}	No.of primary branches plant^{-1}	Pod length (cm)	Grain yield Plant^{-1} (g)
AKTE 12-04 X IPAE 19-21		-1.464	-1.652	-1.166	1.467**	55.414**	-0.317**	0.697	-0.515**	25.742**
21	AKTE 12-04 X ICPL 88039	8.12	1.182	2.666	0.096	7.764	0.198**	-2.636**	-0.287**	5.82
22	AKTE 12-04 X ICPL 151	-0.947	4.682**	2.500	0.428	84.68**	0.071	-0.136	0.138	45.137**
23	BSMR 736 X ICPL 332 WR	-2.302	6.758**	1.757	0.315	8.23	-0.087	-2.091*	-0.389**	5.906
24	BSMR 736 X AL 2255	26.782**	4.091**	2.924	-0.355	44.097**	-0.056	2.742**	-0.331**	13.291**
25	BSMR 736 X AL 882	-30.085**	-2.909**	-4.409*	0.121	-59.903**	-0.111*	-4.258**	0.116	-16.876**
26	BSMR 736 X AL 2207	7.965	-2.409*	-1.075	-0.022	92.564**	-0.251**	2.909**	0.204*	25.171**
27	BSMR 736 X IPAE 20-11	1.265	-5.576**	-1.409	0.537	5.664	0.599**	-1.258	-0.253**	15.011**
28	BSMR 736 X IPAE 19-04	-0.118	4.258**	-0.742	0.901*	1.247	-0.332**	-2.758**	-0.051	8.177
29	BSMR 736 X IPAE 20-5	-11.218**	-3.742**	-3.742*	-0.679	-11.553	-0.136**	-0.924	0.132	-9.313
30	BSMR 736 X IPAE 20-10	3.565	9.091**	3.924*	-0.955*	-3.703	-0.064	2.076*	-0.218*	-7.813
31	BSMR 736 X IPAE 19-21	1.782	-1.242	0.924	-0.582	-18.736**	0.174**	0.242	0.172	-11.244*
32	BSMR 736 X ICPL 88039	-3.085	-0.909	2.757	-0.102	8.064	0.089	1.909*	0.571**	1.589
33	BSMR 736 X ICPL 151	5.448	-7.409**	-0.909	0.821	-65.97**	0.173**	1.409	0.046	-23.899**
	SE(d)±	4.051	1.863	1.684	0.432	5.898	0.048	0.884	0.093	4.775
	CD at 5%	8.154	2.140	3.390	0.869	11.871	0.096	1.763	0.188	9.621
	CD at 1%	10.884	2.857	4.526	1.160	15.847	0.129	2.341	0.251	12.831

* - Significant at 5% level of significance, ** - Significant at 1% level of significance

The hybrids, PDKV Ashlesha x ICPL 88039 (-5.42), BSMR 736 x AL 882 (-4.41), AKTE 12-04 x AL 882 (-4.0) and BSMR 736 x IPAE 20-5 (-3.74) showed significant and negative SCA effects indicating that the possibility to get early maturing hybrids whereas, PDKV Ashlesha x AL 882 (6.48) recorded positive and highly significant SCA effect indicating late maturity (Table 3). High magnitude of SCA variance than GCA variance indicates non additive gene action for this trait. The predominance of non-additive gene action in the inheritance of days to maturity was earlier reported by Srinivas *et al*. (1998), Jayamala and Rathnaswamy (2000), Pandey and Singh (2002), Pandey (2004), Raju and Muthiah (2007) and Patel *et al*. (2010)

Four out of 33 hybrids BSMR 736 x AL 2255 (26.78), PDKV Ashlesha x AL 882 (20.82), PDKV Ashlesha x IPAE 20-5 (9.63) and AKTE 12-04 x AL 882 (9.27) recorded positive significant SCA effects with high *per se* performance for plant height (Table 3). The high SCA effect than GCA effect indicated the importance of non-additive gene action for plant height. These results are in confirmity with the findings of Patel *et al*. (2010) and Patel and Tikka (2015).

Out of 33 hybrids, six hybrids AKTE 12-04 x AL 882 (3.69), BSMR 736 x AL 2207 (2.91), BSMR 736 x AL 2255 (2.74), AKTE 12-04 x IPAE 19-04 (2.19), BSMR 736 x IPAE 20-10 (2.08) and BSMR 736 x ICPL 88039 (1.91) recorded positive and significant SCA effects for number of primary branches per plant. Six hybrids recorded negative and significant SCA effects which was similar with the findings of Patel *et al*. (2010) and Patel and Tikka (2015).

Seven hybrids, BSMR 736x AL 2207 (92.56), AKTE 12-04 x ICPL 151 (84.68), PDKV Ashlesha x AL 882 (78.506), PDKV Ashlesha x IPAE 20-5 (58.01), AKTE 12-04 x IPAE 19-21 (55.41), BSMR 736 x AL 2255 (44.09) and PDKV Ashlesha x ICPL 332 WR (20.04) recorded positive significant SCA effects for number of pods per plant and thirteen hybrids recorded negative significant SCA effects indicating that the trait controlled by non-additive gene action. Non-additive gene action was predominant for pods per plant in the present study and is in agreement with earlier reports of Patil *et al*. (2015) and Patel and Tikka (2015).

Table 4: Mean yield performance, heterosis, GCA and SCA effects in promising crosses.

S.N.	Crosses	Mean seed yield plant^{-1} (g)	Heterosis (%) (H_1)	(H_2)	(H_3)	SCA effects of crosses for yield plant^{-1}	GCA effects of parents for yield plant^{-1}
1	AKTE 12-04 x ICPL 151	121.35	94.39**	80.66**	87.93**	45.14**	-5.71** x 11.54**(L) x (H)
2	AKTE 12-04 x IPAE 19-21	76.82	52.63**	33.21**	18.99**	25.74**	-5.71** x -13.57**(L) x (L)
3	BSMR 736 x AL 2207	120.32	63.33**	26.71**	57.28**	25.17**	5.02** x -13.45**(H) x (L)
4	PDKV Ashlesha x AL 882	81.50	22.28**	-6.71**	26.24**	23.90**	0.69 x 0.99(L) x (L)
5	PDKA Ashlesha x IPAE 20-10	72.81	13.42	-16.71**	12.78**	21.33**	0.69 x 0.26(L) x (L)
6	BSMR 736 x IPAE 20-11	101.32	62.51**	26.44**	15.01**	15.01**	5.02** x 10.93**(H) x (H)

* - Significant at 5% level of significance, ** - Significant at 1% level of significance

H – Parent having good GCA L- Parent having poor GCA

H_1 – Heterobeltiosis, H_2 – Average Heterosis and H_3 – Standard heterosis over best check (PKV Tara)

Among hybrids, AKTE 12-04 x IPAE 19-21 (1.47), ADKV Ashlesha x IPAE 20-10 (1.46), ADKV Ashlesha x AL 2255 (0.94) and BSMR 736 x IPAE 19-04 (0.90) recorded desirable positive and significant SCA effects for 100 seed weight (Table 3). ADKV Ashlesha x IPAE 19-21 (-0.89), AKTE 12-04 x IPAE 20-11 (-0.89), BSMR 736 x IPAE 20-10 (-0.96) and ADKV Ashlesha x ICPL 151 (-1.25) had negative significant SCA effect for 100 seed weight. The importance of non-additive gene action for 100-seed weight as recorded which was similar with the findings of Gupta *et al*. (2011), Patel *et al*. (2010) and Patel and Tikka (2015).

Among hybrids, PDKV Ashlesha x IPAE 19-04 (0.76), AKTE 12-04 x ICPL 332 WR (0.681), BSMR 736 x IPAE 20-11 (0.55), PDKV Ashlesha x AL 2207 (0.198), AKTE 12-04 x ICPL 88039 (0.198), BSMR 736 x IPAE 19-21 (0.17), BSMR 736 x ICPL 88039 (0.17), AKTE 12-04 x IPAE 20-5 (0.17) and PDKV Ashlesha x IPAE 19-21 (0.14) showed significant positive SCA effect with high *per se* performance and were found to be good specific combiners for number of seeds per pod,. Non-additive gene action was found to be important in controlling this character, which was recorded by the Patel *et al*. (2010) and Patel and Tikka (2015).

For pod length, AKTE 12-04 (0.12) recorded highest significant positive GCA effect among the females, PDKV Ashlesha (-0.64) and BSMR 736 (-0.59) recorded significant negative GCA effect. Out of eleven males, ICPL 151 (1.33) and AL 2255 (0.23) recorded significant positive GCA effect.

Among hybrids AKTE 12-04 x ICPL 332 WR (0.59), BSMR 736 x ICPL 88039 (0.57), PDKV Ashlesha x IPAE 19-04 (0.35), PDKV Ashlesha x IPAE 19-21 (0.34), AKTE 12-04 x IPAE 20-10 (0.29), AKTE 12-04 x AL 2255 (0.29) and BSMR 736 x AL 2207 (0.20) showed significant positive SCA effect with high *per se* performance for pod length similar results also recorded by Gupta *et al*. (2011), Patel *et al*. (2010) and Patel and Tikka (2015).

Out of 20 hybrids, 7 hybrids AKTE 12-04 x ICPL 151 (45.14), AKTE 12-04 x IPAE 19-21 (25.74), BSMR 736 x AL 2207 (25.17), PDKV Ashlesha x AL 882 (23.9), PDKV Ashlesha x IPAE 20-10 (21.33), BSMR 736 x IPAE 20-11 (15.01) and BSMR 736 x AL 2255 (13.29) recorded significant SCA effects for grain yield per plant. The relative importance of non-additive gene action for seed yield per plant in the present study also agreement with the results of Patil *et al*. (2015), Patel and Tikka (2015) and Tikle *et al*. (2016).

The hybrids (Table 4) AKTE 12-04 x ICPL 151 (L x H), AKTE 12-04 x IPAE 19-21 (L x L), BSMR 736 x AL 2207 (H x L), PDKV Ashlesha x AL 882 (L x L), PDKV Ashlesha x IPAE 20-10 (L x L), BSMR 736 x IPAE 20-11 (H x H) and BSMR 736 x AL 2255 (H x L) recorded significant SCA effects.

Based on SCA effects and heterosis, the hybrids viz., AKTE 12-04 x ICPL 151, AKTE 12-04 x IPAE 19-21, BSMR 736 x AL 2207, PDKV Ashlesha x AL 882, PDKV Ashlesha x IPAE 20-10,BSMR 736 x IPAE 20-11 were identified as the best specific combiners for yield and yield attributing traits, which can be further utilized for hybrid breeding programme. Based on SCA effects and heterosis, the hybrids viz., PDKV Ashlesha x AL 2255, BSMR 736 x AL 882, PDKV Ashlesha x ICPL 88039, AKTE 12-04 x AL 882, , AKTE 12-04 x IPAE 19-21 and BSMR 736 x IPAE 20-5 were identified as the best specific combiners for earliness.

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'Bunch Trimming' - A Climate Resilient Technology in Banana

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ABSTRACT

The present investigation was carried out during the year 2019-20 to 2021-22 at Agriculture Research Station, Achalpur under Dr. Panjabrao Deshmukh Krishi Vidyapeeth, (M.S.), India to evaluate the effect of bunch trimming on yield, quality and economics of banana crop. The experiment consisted of five different retention of hands treatments was repeated four times in RBD *viz.* 6, 7, 8, 9 and 10 hands immediately after opening of last hand. Pooled data of three years reveled that non-significant effect found in plant height, stem girth, number of leaves, peel weight and pulp to peel ratio in banana. Significantly maximum length of fruit (20.19 cm), girth of fruit (13.80 cm), fruit weight (170.28 g) and pulp weight (115.50 g) recorded in retention of 6 hands bunch^{-1}. Whereas, significantly the maximum number of fruits/bunch (151.22), bunch weight (23.78 kg) and yield (105.59 t ha^{-1}) was noticed in banana by retention of 10 hands bunch^{-1}. Excellent export quality standard fruits, maximum net return and B:C ratio observed in retention of 9 hands bunch^{-1} followed by 8 and 7 hands bunch^{-1}.

Banana (*Musa spp*.) belongs to family *Musaceae* and is native to Malaysia and Burma respectively. Banana known as "Kalpatharu", because of its multipurpose uses from rhizomes to male flowers. It is one of the oldest fruits known to man. In terms of total gross production value, banana is considered the fourth food crop in the world after paddy, wheat and milk. (Adinarayana *et al*., 2016). In the country, Maharashtra state accounts for about 4223.05 thousand MT of the total production from an area of 84.26 thousand hectares with a productivity of 50.12 MT ha^{-1} (Anonymous, 2021). Rodriguez *et al.,* 1988 reported that dry matter would be redistributed among the remaining hands of the bunch helping to increase the size of the remaining hands by removing the terminal hands. Bunch management directly influences yield and quality of banana. The terminal hands of banana bunch are often smaller in size than basal hands. These terminal hands are usually sold as third quality fruits in the market or discarded. Thus, at least two or three hands in a bunch fail to reach the finger required for the export quality standards markets thereby reducing income to the producers. Bunch trimming consists of removing two or three terminal hands of each bunch and is a routine practice in banana production system for export called dehanding.

MATERIAL AND METHODS

The present investigation was carried out at Agriculture Research station at Achalpur of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India during 2019 to 2022 on the cultivar Grand naine. Total 320 tissue culture plants planted with spacing of 1.5 m x 1.5 m were selected for bunch trimming. The experiment consisted of different intensities of hands retention viz. 6, 7, 8, 9 and 10 *viz*. T_1, T_2, T_3, T_4 and T_5, respectively with four replications in RBD. Bunch trimming treatments were done on the bunches immediately after opening of last hand. The floral remnants and male buds were removed. Observations on height of plant, girth of stem, total number of leaves, no. of fruits bunch^{-1}, fruit weight (g), length of fruit (cm), girth of fruit (cm), bunch weight (kg), fruit yield (t ha^{-1}), pulp weight, peel weight and pulp to peel ratio were recorded. For statistical analysis, RBD analysis was done as per the standard procedure given by Panse and Sukatme (1967).

RESULTS AND DISCUSSION

Growth Parameters:

The observation on height of plant, stem girth and total number of leaves were presented in Table 1 and

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found all non significant effect. The highest plant value 184.20 cm and stem girth 54.75 cm with treatment T_5- retention of 10 hands, however highest number of leaves with treatment T_3- retention of 8 ands

Table 1: Pooled values of plant height (cm), stem girth (cm) and number of leaves of banana.

S. N.	Treatments	Pooled data of three years 2019-20, 2020-21 and 2021-22		
		Plant height (cm)	Stem girth (cm)	Number of leaves
1.	Retention of 6 Hands	183.64	54.65	23.58
2.	Retention of 7 Hands	183.08	53.83	23.68
3.	Retention of 8 Hands	182.07	54.02	24.20
4.	Retention of 9 Hands	181.87	55.53	23.75
5.	Retention of 10 Hands	184.20	54.75	24.02
	SE m±	1.06	0.66	0.46
	C.D. 5%	-	-	-

Yield Parameters and Yield

The observation on number of fruits per bunch, fruit weight, length of fruit, girth of fruit, bunch weight, fruit yield (t ha^{-1}), pulp and peel weight and pulp to peel ratio were recorded and presented in Table 2. Different bunch trimming treatment reported significant differences in respect of yield parameters and yield.

Significantly maximum number of fruits per bunch (151.22), maximum bunch weight (23.78 kg) and yield (105.59 t ha^{-1}) were noticed in retention of 10 hands $bunch^{-1}$ followed by retention of 9, 8, 7 and 6 hands. Similar results of three hands removal reduced total yield reported by Irizarry *et al.,* (1992). Removal of 1, 2 and 3 lower hands reduced yield by 9, 12.7 and 17.4 per cent, respectively in cultivar Alpan also reported by Mandal and Sharma (2000).

Significantly maximum fruit weight (170.28 g), length of fruit (20.19 cm), girth of fruit (13.80 cm) and pulp weight (115.50 g) were noticed in retention of 6 hands $bunch^{-1}$ followed by retention of 7, 8, 9 and 10 hands. Increase in fruit weight because of reduction in sink size due to dehanding might be due to higher rate of fruit filling (Jullien *et al.,* 2001). Longer size fruit was attained with hand tear off at 20 days after flowering and leaving 4-6 hands per bunch in banana hybrid FHIA-21 reported by Arcila *et. al.* (2002).

Economics of bunch trimming

Economics presented in Table 3 indicated that, retention of 9 hands per bunch recorded highest export quality yield 100.57 t ha^{-1}, net return of Rs 1031397/- and B:C ratio 4.74 which was followed by retention 8 hands. Lowest yield, net return and B:C ratio (85.71 t ha^{-1}, Rs 838146 and 4.04) recorded in retention of 6 hands. Digal (2016) reported that maintaining of 9 hands $bunch^{-1}$ found better for higher yields and net realization in grand naine banana.

CONCLUSION

Non-significant effect found in height of plant, girth of stem, total number of leaves, peel weight and pulp to peel

Table 2: Effect of bunch trimming on yield parameters and yield of banana (Pooled data of three years).

S. N.	Treatments	Pooled data of three years 2019-20, 2020-21 and 2021-22								
		No. of fruits $bunch^{-1}$	Fruit weight (gm)	Length of fruit (cm)	Girth of fruit (cm)	Bunch weight (kg)	Fruit Yield t ha^{-1}	Pulp weight	Peel weight (g)	pulp to peel ratio
1	Retention of 6 Hands	113.33	170.28	20.19	13.80	19.30	85.71	115.50	40.13	2.94
2	Retention of 7 Hands	121.93	168.17	19.14	12.81	20.50	91.03	110.38	41.38	2.69
3	Retention of 8 Hands	132.83	163.92	18.77	12.56	21.78	96.69	106.88	40.25	2.69
4	Retention of 9 Hands	140.42	161.32	18.39	12.27	22.65	100.57	104.63	39.00	2.71
5	Retention of 10 Hands	151.22	157.27	17.75	12.07	23.78	105.59	100.75	38.13	2.67
SE m±		0.81	0.94	0.15	0.14	0.20	0.91	1.13	1.53	0.12
C.D. 5%		2.48	2.90	0.45	0.42	0.63	2.79	3.48	-	-

Table 3: Economics of bunch trimming in banana for export purpose cv. grand naine

S. N.	Treatments	Yield (t ha^{-1})	Gross Income (Rs ha^{-1})	Cost of Cultivation (Rs ha^{-1})	Net return (Rs ha^{-1})	B : C Ratio
1	Retention of 6 Hands	85.71	1114170	276024	838146	4.04
2	Retention of 7 Hands	91.03	1183388	276024	907364	4.29
3	Retention of 8 Hands	96.69	1256961	276024	980937	4.55
4	Retention of 9 Hands	100.57	1307421	276024	1031397	4.74
5	Retention of 10 Hands	105.59*	718012	276024	441988	2.60*

- Banana fruit selling rate of export Rs 13000/- per ton.
- Banana fruit selling rate of 10 hands banana (NEE) Rs 6800/-per ton

* Retention of 10 Hands = not eligible for export (NEE)

ratio in banana. Whereas length of fruit, girth of fruit, number of fruits bunch^{-1}, fruit weight, bunch weight, yield ha^{-1} and pulp weight had significant effect. Maximum length of fruit, girth of fruit, fruit weight and pulp weight recorded in retention of 6 hands bunch^{-1} whereas, significantly minimum length of fruit, girth of fruit, fruit weight and pulp weight recorded in retention of 10 hands per bunch. Significantly the maximum number of fruits/ bunch, bunch weight and yield t ha^{-1} was noticed in banana by retention of 10 hands bunch^{-1}. However, significantly minimum number of fruits bunch^{-1}, bunch weight and yield t ha^{-1} recorded with the retention of 6 hands bunch^{-1}. Maximum export quality standard fruit, net return and B:C ratio observed in retention of 9 hands per bunch followed by 8 and 7 hands bunch^{-1}. Considering the yield, quality and economics of banana, retention of 9 hands per bunch is recommended for export purpose of banana.

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Productivity and Fertility Of Soil As Influenced By Integrated Nutrient Management On Roselle (*Hibiscus Sabdariffa* L.)

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ABSTRACT

A field experiment was undertaken during 2023-24 to study the combined use of vermicompost and synthetic fertilizer on soil fertility. The experiment was laid out in randomized block design (RBD) with five treatments and five replications. The treatments were T_1- 100 % RDF (40:20:40 NPK), T_2- 75 % RDF + 25% N through vermicompost, T_3- 50% RDF + 50 % N through vermicompost, T_4- 100 % N through vermicompost, T_5- Absolute control. The yield parameters like seed yield, biological yield and stalk yield and soil parameters like pH, EC, soil organic carbon (%), soil available nutrients (kg ha^{-1}), nutrient uptake (kg ha^{-1}) were studied. Significantly highest yield and dry matter accumulation and highest N, P, and K uptake was recorded in 100% RDF treatment, followed by 75% RDF + 25% N through vermicompost. Post harvest soil analysis showed that soil fertility status was enriched in respect of organic carbon, available N, P and K where synthetic fertilizers was incorporated in association with vermicompost.

Mesta (*Hibiscus spp.)* is one of the important fibre crops and stands next only to jute in production. It is the nearest ally of jute (*Corchorus sp*.) and plays an effective role in supplementing the short supply of raw material in jute industry. Mesta is a commercial crop in many tropical and subtropical countries (Anonymous, 2022). Two species of mesta viz., *Hibiscus sabdariffa* and *Hibiscus cannabinus* belonging to the family Malvaceae are cultivated. The economic value of roselle encompasses its leaves, flowers, fruits, and seeds. In 2016-17 area under mesta in India is about 0.68 lakh ha with a production of about 5.64 lakh bale. Bihar being the major mesta growing state shared 24.5 % and 43.6% of total area and production, respectively. Mesta is grown in considerable area in Maharashtra (12.4%) but their production is less to the tune of 2.3 %. (Anonymous, 2018)

Imbalanced use of chemical fertilizers lowers crop productivity and soil fertility. Roselle is mainly grown by marginal farmers. The high cost of fertilizers discourages farmers for balanced application of nutrients which leads to low productivity of roselle. Combined use of vermicompost and synthetic fertilizers would be quite promising not only in providing greater stability in roselle production, but also maintaining higher soil fertility status. Keeping these points in view, the present study was undertaken to evaluate the effect of integrated nutrient management on soil fertility in roselle (*H. sabdariffa* L.).

MATERIALS AND METHODS

The experiment was conducted during *kharif* season of 2023-24 at farm of Agro Ecology and Environment Centre (AEEC), Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.). Soil of experimental plot was clayey in texture and slightly alkaline in nature having pH- 8.16, EC- 0.28 dsm^{-1}, low organic carbon (0.44%), low in available Nitrogen (165.2 kg/ha), phosphorus (17.81 kg/ha) and high in potash (324.54 kg/ha).

The experiment was carried out in a randomized block design, with five treatments with five replications. The treatments comprised of T_1- 100 % RDF (40:20:20 NPK), T_2- 75 % RDF + 25% N through vermicompost, T_3- 50% RDF + 50 % N through vermicompost, T_4- 100 % N through vermicompost, T_5- Absolute Control.The recommended dose of fertilizers 40:20:20,NPK Kg $^{-1}$ ha was applied in form of urea, single superphosphate and muriate of potash, respectively. Vermicompost was added on nitrogen percentage (Oven dry weight) basis. Nitrogen, phosphorus and potassium content in vermicompost were 1.5 %, 0.5%, 0.8% respectively. Roselle crop was fertilized as per the treatments. The roselle crop was sown @5 kg seed ha^{-1} on 14thJuly of 2023, after receiving sufficient amount of precipitation. The data on seed yield, biological yield, stalk yield, nutrient uptake, soil available nutrient, pH, EC, and organic carbon were analysed statistically using ANOVA.

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RESULTS AND DISCUSSION

Effect of INM on yield parameters

Data pertaining to yield parameters (Table 1) showed that application of 100% RDF recorded significantly higher seed yield (700 kg ha^{-1}) which was at par with the treatment 75% RDF+25% N through vermicompost (667 kg ha^{-1}). Similarly the treatment 100% RDF recorded significantly higher biological yield (3095 kg ha^{-1}) and stalk yield (2395 kg ha^{-1}) which was at par with treatment T_2 (75% RDF + 25% N through vermicompost) in terms of biological yield (2884 kg ha^{-1}) and stalk yield (2217 kg ha^{-1}). The increased in yield of roselle due to integration of nutrients sources might be attributed to favourable effect of organic manures and synthetic fertilizers in supply of balance nutrients through mineralization and improvement in physico-chemical properties of soil. Similar findings were recorded by Akanbi *et al*. (2009), Dahmardeh, (2012) Norhayati *et al.* (2019), Al-Sayed, *et al*. (2019).

Effect of integrated nutrient management on pH, EC and Organic carbon (%)

The data presented in the table 2 revealed that, a slight decrease in soil pH values as result of organic amendments. The decrease in soil pH due to vermicompost might result from the release of organic acids and carbon dioxide into the soil during the decomposition of the manure. Soil EC is a measure of concentration of ions from water soluble salts in soils and the test results are indicative of soil salinity. The data presented in the table 2 revealed the difference observed between the initial and final status of EC. As compared to initial soil EC status (0.28 dSm^{-1}) variation observed that decreased in EC and mean EC was (0.26 dSm^{-1}). Soil organic carbon is a measurable component of soil organic matter and refers to the carbon content of organic compounds. The increase in organic carbon in different treatments was due to the addition of vermicompost which promote nutrient cycling and microbial activity. Organic C content increased with inorganic fertilizers in combination with organic fertilizers but the increase was not significant. Also, addition of organic matter result in higher crop growth and biomass addition due to leaf shedding and root biomass might have contributed to higher soil organic carbon content. Similar findings were recorded by Acharya *et al*. (1988), Meena *et al.* (2018), Saha *et al*. (2010).

Effect of integrated nutrient management on Nutrient Availability

Data revealed that after harvest of the crops available N content increases in soil from the initial status. The maximum available N was observed with treatment T_1 (179.32 kg ha^{-1}) followed by treatment T_2 (176.36 kg ha^{-1}). The increase in available nitrogen status under integrated treatments might be due to greater multiplication of soil microbes as a result of which organically bound nitrogen was converted to inorganic form of nitrogen (Bharadwaj and Omanwar, 1994). Available P content increases in soil from the initial status. The initial available Phosphorus was 17.81 kg ha^{-1}. The maximum available P was observed with treatment T_1 (22.54 kg ha^{-1}) followed by treatment T_2

Table 1: Seed yield (kg ha^{-1}), Stalk yield (kg ha^{-1}) and Biological yield (kg ha^{-1}) of roselle as influenced by different nutrient management treatments

Symbols	Treatments	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Stalk yield (kg ha^{-1})
T_1	100% RDF	700	3095	2395
T_2	75% RDF + 25% N through Vermicompost	667	2884	2217
T_3	50% RDF + 50% N through Vermicompost	575	2473	1898
T_4	100% N through Vermicompost	523	2235	1712
T_5	Absolute Control	324	1583	1259
	SE (m) ±	27.31	97.20	100.77
	CD at 5%	81.87	291.40	302.12

Table 2 : pH, EC (dS m^{-1}), OC (%), Available NPK (kg ha^{-1}) of roselle as influenced by different integrated nutrient management treatments

Treatments	pH	EC(dS m^{-1})	OC(%)	N(kg ha^{-1})	P(kg ha^{-1})	K(kg ha^{-1})
T_1 - 100% RDF	8.15	0.27	0.450	179.32	22.54	339.16
T_2 - 75% RDF + 25% N through Vermicompost	8.15	0.27	0.454	176.36	20.85	336.60
T_3 - 50% RDF + 50% N through Vermicompost	8.14	0.26	0.462	173.49	19.01	330.40
T_4 - 100% N through Vermicompost	8.14	0.25	0.472	168.20	18.52	326.80
T_5 - Absolute Control	8.14	0.26	0.442	158.89	15.55	323.40
SE (m) ±	0.01	0.01	0.006	0.84	0.40	0.95
CD at 5%	NS	NS	NS	2.51	1.19	2.84
Initial status	8.16	0.28	0.446	165.20	17.81	324.54

(20.85 kg ha^{-1}). The increase in phosphorus in treatment receiving verimicompost was might be due to the release of organically bound P during decomposition of organic matter solubilisation of soil P by organic acids produced during decomposition of organic matter (Roy *et al.,* 2001). Available K content increases in soil from the initial status.. The maximum available K was observed with treatment T_1 (339.16 kg ha^{-1}) followed by treatment T_2 (336.60 kg ha^{-1}). The increase in available K attributed to the addition of vermicompost might be attributed to the direct addition of potassium into the available K pool in soil. Similar findings were recorded by Saha *et al*., (2010), Gupta *et al.,* (1988) and Shafi *et al*., (2012).

Effect of integrated nutrient management on nutrient uptake

Total nitrogen, phosphorus and potassium uptake by roselle crop estimated from both seed and straw. Nitrogen uptake showed variation as influenced by different nutrient management treatments.. Among the different nutrient management treatments, treatment T_1 (100% RDF) recorded highest N uptake i.e. 30.5 kg ha^{-1} which was followed by treatment T_2 (75% RDF + 25 % through vermicompost). Lowest nitrogen uptake was recorded in treatment T_5 (Absolute control) . The higher nutrient uptake with vermicompost might be attributed to solubilisation of native nutrients, chelating of complex intermediate organic molecules produced during decomposition of vermicompost, mobilization and accumulation of different nutrients in different plant parts. Similar findings were recorded by Dosani *et al*. (1999). Among the different nutrient management treatments, treatment T_1 (100% RDF) recorded highest P uptake followed by treatment T_2 (75% RDF + 25% N through vermicompost). Lowest phosphorus uptake was recorded in treatment T_5 (Absolute Control) 4.9 kg ha^{-1}. The application of phosphorus fertilizer would lead to increased phosphorus content in soil and plants. Among the different nutrient management treatments, treatment T_1 (100% RDF) recorded highest K uptake i.e. 23.6 kg ha^{-1} which was followed by treatment T_2 (75% RDF + 25% N through vermicompost). Lowest potassium uptake was recorded in treatment T_5 (Control). The application of potassium fertilizer would lead to increased potassium content in soil and would increase its concentration in plants. Similar findings were recorded by Himawati *et al*., (2018) and Akhtar *et al.,* (2019).

Effect of integrated nutrient management on soil microbial population.

Soil microbial population in the rhizosphere includes fungi, bacteria and actinomycetes and wide range of living organisms. The bacterial, fungal and actinomycetes count was found maximum in treatment T_4 (100% N through vermicompst), followed by treatment T_3 (50% RDF + 50% N through vermicompost)and minimum microbial count was recorded in treatment T_5 – Absolute control There was variable build-up of total microbial activity in the soil under various treatments. Integration of vermicompost with NPK not only increased microbial population in the soil but also increased organic carbon content in soil. The overall maximum microbial count was

Table 3. Total Nitrogen uptake of roselle as influenced by different integrated nutrient management treatments

Treatments		N (kg ha^{-1})			P_2O_5 (kg ha^{-1})			K_2O (kg ha^{-1})		
		Seed	Straw	Total	Seed	Straw	Total	Seed	Straw	Total
T_1	100% RDF	12.2	18.2	30.5	3.4	7.9	11.3	4.0	19.6	23.6
T_2	75% RDF + 25% N through Vermicompost	11.6	16.6	28.2	3.1	7.1	10.2	3.7	18.0	21.6
T_3	50% RDF + 50% N through Vermicompost	9.8	13.9	23.7	2.6	5.9	8.5	3.1	15.2	18.3
T_4	100% N through Vermicompost	8.9	12.3	21.3	2.4	5.3	7.7	2.7	13.0	15.8
T_5	Absolute Control	4.8	8.06	13.4	1.4	3.5	4.9	1.5	7.6	9.0
	SE (m) ±	0.46	0.76	0.78	0.13	0.33	0.32	0.14	0.82	0.80
	CD at 5%	1.39	2.28	2.35	0.38	0.98	0.96	0.43	2.45	2.38
	GM.	9.51	13.91	23.4	2.58	5.94	8.52	2.99	14.67	17.66

Table 4 . Microbial studies as influenced by different nitrogen management treatments

Treatments		Bacteria (CFU x 10^6 g^{-1} soil)	Fungi (CFU x 10^4 g^{-1} soil)	Actinomycetes (CFU x 10^4 g^{-1} soil)
T_1	100% RDF	22.88	16.88	21.13
T_2	75% RDF + 25% N through Vermicompost	23.60	18.58	23.02
T_3	50% RDF + 50% N through Vermicompost	29.78	20.73	25.40
T_4	100% N through Vermicompost	32.62	23.10	26.77
T_5	Absolute Control	19.92	15.64	18.97
	SE (m) ±	0.48	0.36	0.34
	CD at 5%	1.43	1.08	1.01
	GM.	25.76	18.99	23.06

recorded in treatment T_4 due the use of higher quantity of vermicompost. Similar improvements in microbial activities were recorded by Majumdar *et al*., (2007) and Saha *et al.,* (2008).

CONCLUSION

From the present study it is concluded that the treatment 75% RDF + 25% N through vermicompost enhance avaibility of nutrients, nutrient uptake, organic carbon and microbial population, reduces the use of synthetic fertilizer by 25%.

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Study on Effect of Spirulina Powder Treated Mulberry Leaves on Biological Traits of *Bombyx Mori*

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ABSTRACT

The present investigation entitled "Study on effect of spirulina powder treated mulberry leaves on biological traits of *Bombyx mori*" was carried out during 2024-2025 was undertaken with the objective *viz*., to study the effect of spirulina powder on development traits of silkworm. The experiment was conducted at Sericulture Laboratory, Department of Entomology, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during September 2024 to December 2024. The design used in the experiment was Completely Randomized Block Design with seven treatments and three replications. Treatments viz., T1 (0.5 gm spirulina powder solution), T2 (1.0 gm spirulina powder solution), T3 (1.5 gm spirulina powder solution), T4 (0.5 gm spirulina powder + 1% honey solution), T5 (1.0 gm spirulina powder + 1% honey solution), T6 (1.5 gm spirulina powder + 1% honey solution) and T7 untreated (control). The larvae were fed with fresh mulberry leaves up to 3rd moult. After 3rd moult the larvae were fed with treated leaves on alternate days in 4th and 5th instar and their impact on silkworm development. The study revealed among all the seven treatments used, T6 i.e. (1.5 gm spirulina powder + 1% honey solution) showed the best results for the moth emergence (97.26 per cent), fecundity (554.6), hatching percentage (97.83 per cent), pupal duration (10.98) and larval duration (23.60 days). These findings suggest that incorporating spirulina powder and honey into the silkworm diet can significantly enhance development traits of silkworm, thereby offering valuable insights for improving sericulture practices.

Silk is known as "The Queen of Fibers" and because of its huge surface area and capacity for reproduction it offers microorganisms an ideal home. (Guangyu *et al*. 2014). The process of growing, breeding and management of silkworms to get pure raw silk is sericulture. The word Sericulture is derived from the Greek word 'sericos' meaning 'silk' and the English word 'culture' meaning 'rearing' (Bobade *et al.* 2019). Since its discovery in 2700 BC, silkworms have been used all over the world to produce natural silk in the shape of cocoons. Sericulture industry plays a big role in both of the global and rural economics of India.

Mulberry trees which are deciduous trees that grow wild and are also cultivated in many tropical and temperate regions of the world are members of the family Moraceae of the genus *Morus*. Mulberry silkworms can easily digest and enjoy eating mulberry leaves. The leaves and young stems had protein contents ranging from 15% to 28%. There are nearly no harmful substances or anti-nutritional elements for mulberry silkworms and the mineral content is higher. Currently, the total silk production in India is the highest among comparable agricultural crops. The nutritional intake of the silkworms has a direct impact on their genetic makeup, as well as various characteristics such as cocoon quality, pupation, silk production and reproductive traits (Rathod *et al*. 2015).

India is the 2nd largest producer of silk in the world. Around 9.76 million people are directly or indirectly associated with sericulture industry in rural and sub-urban during 2021-22 was 34,903MT, with an increase of 3.4% over the previous year. Out of this huge production, mulberry silk-type has highest share in silk production with 71%. India's silk and silk products are in high demand throughout the world. In recent years attempts have been made to supplement nutrient, such as proteins, carbohydrates, amino acids, vitamins, sterols, hormones, antibiotics, plant extracts etc. for better performance of silkworms (Sannappa *et al*. 2002). In terms of sericulture, Maharashtra is an unconventional state that produces Tasar and Mulberry silk. The state is unique in that it produces 98% of its own bivoltine sericulture, ranking highest among unconventional states and one of India's potential silk-producing states. Although the development of bivoltine sericulture has been one of the Indian silk

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industry's key areas its output has not yet reached the desired levels (Bobade *et al*. 2019). Currently in the 2023-2024 fiscal year, India produced 38,913 MT of raw silk. India has a distinct advantage of practicing sericulture throughout the year, yielding a stream of 4- 6 crops as a result of its tropical climate.

MATERIAL AND METHODS

The present investigation was undertaken to study the effect of spirulina powder on the development and economic traits of silkworm hybrid FC_1 x FC_2 on V-1 variety of Morus alba. The investigation was undertaken during September 2024 to December 2024. The experiment was conducted at Sericulture Laboratory, Department of Entomology, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The design used in the experiment was Completely Randomized Block Design with seven treatments and three replications. The treatments details are shown in Table 1. Disease free laying of silkworm hybrid Fc_1 x Fc_2 procured from Central Sericulture Research & Training Institute, Mysore was used as test hybrid against mulberry variety G4 as feed of silkworm, in present investigation the fresh mulberry leaves of V-1 variety were obtained from already established mulberry plantation at the field, Department of Entomology, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

Table 1: Treatment details

Treatments	Detail
T1	Feeding of mulberry leaves treated with spirulina powder 0.5 gm / 100 ml of distilled water.
T2	Feeding of mulberry leaves treated with spirulina powder 1.0 gm / 100 ml of distilled water.
T3	Feeding of mulberry leaves treated with spirulina powder 1.5 gm / 100 ml of distilled water.
T4	Feeding of mulberry leaves treated with spirulina powder 0.5 gm + 1% honey /100 ml of distilled water.
T5	Feeding of mulberry leaves treated with spirulina powder 1.0 gm + 1% honey /100 ml of distilled water.
T6	Feeding of mulberry leaves treated with spirulina powder 1.5 gm + 1% honey /100 ml of distilled water.
T7	Untreated

Rearing Method

In order to ensure homogeneous embryo growth, the disease-free laying (DFLs) of FC1 X FC2 bivoltine mulberry silkworms, which were acquired from Central Sericulture Research and Training Institute, Mysore, were put in a black box, covered with a black piece of fabric, and left undisturbed for 48 hours. Mulberry plantations of V-1, which were well-grown, were used as feed for the silkworm race.

The enhanced silkworm rearing method suggested by Krishnaswami (1978) was applied in this investigation. Two-by-three-foot plastic trays were used to hold disease-free eggs (DFLs). Freshly chopped young mulberry leaves of the V-1 kind were given to the newly hatched silkworm hybrid larvae. Weak larvae were routinely eliminated during the rearing period, and 200 healthy larvae were maintained in several replicates per tray following the third moult. Four times a day, the freshly hatched worms were fed with mulberry leaves that had been coarsely chopped into 0.5 to 1.5 cm^2 pieces. Up until the fourth moult, the rearing trays were cleaned twice following the second moult and once following the first. All rearing equipment was thoroughly cleaned using the proper disinfectants and according to suggested schedules before, during, and after the silkworm larvae were grown. The rearing trays were cleaned twice before the second moult and once following the first. Until their third moult, the larvae were fed fresh mulberry leaves. On alternate days (days 1, 3, 5, 7) following the third moult, the larvae in the fourth and fifth instar were fed treated leaves until they began spinning their cocoons.

During its larval stage, the silkworm grows through four moults. There are five major phases to its growth. Since each stage in between two consecutive moults is referred to as a "instar," there are five instars in the silkworm life cycle. Since the worms stop feeding throughout the moulting process, there is no food available. Within twenty or thirty hours, moulting is finished. Feeding was resumed after a 30-minute break

once each moult was finished. Vijetha, a bed disinfectant, was sprayed at a rate of 4 grams per 100 Disease-Free Layings (DFLs) to prevent infections. The rearing bed was subsequently disinfected.

On the fifth or sixth day following the worms' placement on the "netrika" for spinning, the cocoons were harvested. Ten cocoons were selected at random from each treatment group in order to evaluate the cocoon's qualities. Ten fully grown larvae's weight, the length of the larval stage, the weight of a single cocoon, the weight of its shell, the shell ratio, the Effective Rate of Rearing (ERR), and the length of the cocoon filament were among the data that were recorded.

Method of recording observations

2.1. Moth emergence (%)

The observations on the number of moths emerged from cocoon was recorded and it was expressed in percentage.

$$\text{Moth emergence (\%)} = \frac{\text{Number of moths emerged}}{\text{Total no. of cocoons}} \times 100$$

2.2. Fecundity (no of eggs / female)

The fecundity of silkworms from each treatment was computed by taking number of eggs laid by female after mating.

3. Hatching (%)

$$\text{Hatching (\%)} = \frac{\text{No. of hatched eggs}}{\text{Total no. of eggs}} \times 100$$

4. Pupal duration (days)

The total pupal period was measured by recording period from spinning to the emergence of moth.

5. Larval duration (days)

The total larval period was measured by recording the period from hatching to the onset of spinning.

3.Results and Discussion

This research aimed to assess the profound effects of feeding the spirulina powder and honey treated mulberry leaves of V-1 variety on the biological traits of various silkworm hybrids. The compelling findings from this study are comprehensively presented in this research under the following headings.

3.1. Moth emergence

The moth emergence varied in the range of 90.26 to 97.26 per cent. Significantly highest moth emergence (97.26 %) was recorded in the treatment where mulberry leaves treated with spirulina powder 1.5g + honey 1%, which was found significantly superior with rest of the other treatments. The next best treatment in respect of moth emergence were observed in untreated (94.67 %), spirulina powder 1.0 g + 1% honey (94.26 %), spirulina powder 0.5 g + honey 1% (93.85 %), spirulina powder 1.5 g (93.04 %) and spirulina powder1.0g (92.33 %), which were found statistically at par with each other. The lowest treatment recorded for moth emergence with mulberry treated leaves of treatment spirulina powder 0.5 g (90.26 %).

These results are in conformity with the findings of Muhammad *et al*. (2006) who reported that larvae fed on combination of macro and micronutrients recorded 77.41 per cent moth emergence of *B. mori*.

Fecundity

The fecundity was recorded in range of 435 eggs/ female to 554.6 eggs/ female. Data revealed that the significantly maximum fecundity was recorded in the treatment where mulberry leaves treated with spirulina powder 1.5g + honey 1% (554.6 eggs/ female) followed by spirulina powder 1.0g + honey 1% (526.00 eggs/ female). These two treatments are significantly superior over rest of the others treatments. The next best treatment in respect to fecundity spirulina powder 0.5 g + honey 1% (495.00 eggs/ female), spirulina powder 1.5g (484.6 eggs/ female), spirulina powder 1.0 g (473.30 eggs/ female), spirulina powder 0.5g (455.6 eggs/ female) and untreated (435.00 eggs/ female), which were found statistically at par with each other.

These results are in accordance with the findings of Gad (2013) who reported that supplementation of honey increased the number of deposit eggs per female more than control. El-sayed (1999) *et al*. observed that the

mixture of honey and black cumin seeds increased number of deposit eggs per female. Zannoon (1994) have also reported that various solutions of honey increased number of deposited eggs per female than control.

Shruti *et al*. (2019) reported that the number of eggs / laying was significantly higher in azolla (613.40) followed by soy milk, yeast and Spirulina (516.87 to 572.20).

It is well known that probiotics contain nutrient supplements such as proteins, carbohydrates, amino acids, vitamins, sterols, hormones, antibiotics etc. and are known to influence the growth and development as well as health of organisms and accordingly the resulting moths would be robust and heavy weighing, consequently lay a greater number of eggs when compared to control.

Hatching percent (%)

The percent egg hatching was recorded in range of 90.67% to 97.83%. Data revealed that the significant maximum percent egg hatching was recorded in mulberry leaves treated with spirulina powder 1.5g + Honey 1% (97.83%). However, this treatment was found superior over the rest of other treatments. The next best treatment in terms of egg hatching percent was mulberry leaves treated with spirulina powder 1.0g + honey 1% (94.83%), spirulina powder 0.5g + honey 1% (93.40%), spirulina powder 1.5 g (92.33%), spirulina powder 1.0g (92.17) and spirulina powder 0.5g (91.17%), which were found statistically at par with each other. The lowest egg hatching percentage was observed in untreated (90.67%).

These results are in agreement with the findings of Pal and Datta (2003) who showed that hatching percentages of *B. mori* eggs increased significantly due to the treatment of ascorbic acid. Muhammad *et al*. (2006) observed that larvae of *B. mori* fed on combination of macro and micronutrients registered 89.07 per cent hatchability.

Pupal Duration

The data revealed that pupal duration varied in the range of 10.98 days to 12.78 days. The significantly shortest pupal duration was recorded in mulberry leaves treated with spirulina powder 1.5g + honey 1% (10.98 days), spirulina powder 1.5g (11.67 days), spirulina powder 1.0g + honey 1% (11.75 days) and spirulina powder 1.0g (11.83 days), which was found superior over rest of the other treatments. However, these four treatments were found statistically at par with each other. The next best treatment in terms of pupal duration was mulberry leaves untreated (12.33 days) and spirulina powder 0.5g + Honey 1% (12.57 days) which were comparable with each other. The longest pupal duration was observed in mulberry leaves treated with spirulina powder 0.5g (12.78 days).

The results of present investigation are in harmony with findings of Fathy, H.M. *et al*. (2007) who recorded that the supplementation of honey with mulberry leaves gave pupal durations significantly shorter than control. Additional support for these findings was provided by the research of Pawar (2024) and Sonone (2024).

Larval Duration

Data revealed that the significantly shortest larval duration was observed in mulberry leaves treated with spirulina powder 1.5 g + honey 1% (23.60 days), which was found statistically at par with spirulina powder 1.0g + honey 1% (24.65 days). However, these two treatments were found best over the rest of the other treatments. The next best treatment in respect of larval duration was recorded in mulberry leaves treated with spirulina powder 0.5 g + 1% honey (25.14 days), spirulina powder 1.5g (25.35 days), spirulina powder 1.0g (25.80 days), spirulina powder 0.5g (25.82 days) and untreated (26.55 days). However, these six treatments which were found statistically at par with each other. The longest larval duration shown by mulberry leaves untreated (26.55 days).

These results are in accordance with the findings of Fathy, H.M. *et al*. (2007) who recorded that the supplementation of honey with mulberry leaves gave larval durations significantly shorter than control.

Mathavan *et al.* (1984) reported that final instar of *Bombyx mori* L. fed on mulberry leaves supplemented with *Spirulina fusiformis* (Worohichin), a single cell protein (SCP) required only six days to attain spinning stage as against the control (nine days). Roger and Chen (1984) reported that larvae reared on diets of powdered blue-green algae, *Spirulina platensis* (Nordst) with 30 to 40 per cent algal powder had shorter fourth instar larval duration.

Table 1. Biological traits of bivoltine silkworm on V-1 mulberry variety treated with spirulina powder and honey.

Treatment details	Moth emergence (%)	Fecundity (no)	Hatching (%)	Pupal duration	Larval duration
T_1 - Spirulina powder 0.5g	90.26 (71.83)	455.6	91.17 (72.72)	12.78	25.82
T_2 - Spirulina powder 1.0g	92.33 (73.95)	473.3	92.17 (73.76)	11.83	25.80
T_3 - Spirulina powder 1.5g	93.04 (74.70)	484.6	92.33 (73.95)	11.67	25.35
T_4 - Spirulina powder 0.5g + Honey 1%	93.85 (75.71)	495.0	93.40 (75.15)	12.57	25.14
T_5 - Spirulina powder 1.0g + Honey 1%	94.26 (76.17)	526.0	94.83 (76.91)	11.75	24.65
T_6 - Spirulina powder 1.5g + Honey 1%	97.26 (80.57)	554.6	97.83 (81.75)	10.98	23.60
T_7 - Untreated	94.67 (76.68)	435.0	90.67 (72.25)	12.33	26.55
SE (m) ±	0.75	6.79	0.82	0.33	0.46
CD at 5%	2.27	20.59	2.49	1.00	1.39
CV (%)	1.71	2.40	1.89	1.38	3.14

*Figures in parentheses indicate arc sin transformed values.

Roychoudhary *et al.* (1994) who reported that fifth instar bivoltine hybrid reared on artificial diet containing protein supplements had a short larval duration as compared to larvae reared on mulberry leaf alone.

CONCLUSION

The study revealed that among all the seven treatments used, T6 i.e. (Spirulina powder 1.5g + 1% honey solution) showed the best results for the moth emergence (97.26 per cent), fecundity (554.6), hatching percentage (97.83 per cent), pupal duration (10.98) and larval duration (23.60 days). These findings suggest that incorporating spirulina powder and honey into the silkworm diet can significantly enhance development traits of silkworm, thereby offering valuable insights for improving sericulture practices.

It is concluded from the present investigation that T6 i.e. mulberry leaves treated with Spirulina powder 1.5g + 1% honey solution recorded a positive effect on development parameters than untreated control batch.

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Study of Biological Traits of Different Silkworm Hybrids on G-4 Cultivar of Mulberry

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ABSTRACT

The present investigation was conducted to study the biological traits of bivoltine silkworm hybrids on the G-4 mulberry variety at the Sericulture Laboratory, Department of Entomology, Post graduate Institute, Dr. P.D.K.V., Akola, during 2024-2025, using a Completely Randomized Design with seven treatments and three replications. Disease-free layings of silkworm hybrids, including $FC_1 \times FC_2$, $FC_2 \times FC_1$, $TT_{21} \times TT_{56}$, $TT_{56} \times TT_{21}$, $S_8 \times CSR_{16}$, $SR_{16} \times S_8$ and $SK_6 \times SK_7$, were procured from the Central Sericultural Research and Training Institute in Mysore, Karnataka. During study, it was observed that, among all the hybrids used for rearing, CSR_{16} X S_8 found the significantly superior over the rest of other hybrids tested in case of larval duration (22.61 days), egg hatching (97.01%), pupal duration (9.94 days), moth emergence (96.41%) and for fecundity (543.49) $FC_1 \times FC_2$ shows best result. It can be concluded that the bivoltine hybrid CSR16 X S8 and FC1 × FC2, reared on the mulberry variety G-4, was superior to all other hybrids tested under Vidarbha conditions.

The term "Sericulture" originates from the Greek word "sericos," meaning "silk," combined with the English word "culture," which refers to "rearing." Sericulture involves the rearing of silkworms for the production of raw silk. The silkworm, scientifically known as Bombyx mori L., is a lepidopteran insect that plays a significant role in the production of natural fibres (Bobade et al. 2019). Sericulture is the practice of raising silkworms in artificial or domesticated conditions and extracting raw silk from their cocoons. Bombyx mori is an important economic insect that transforms plant protein, particularly from mulberry into animal protein in the form of silk (Simi Simon et al. 2024). The mulberry plant is the initial choice of mulberry silkworms. It is believed that mulberry plant is native of India or China particularly from lower slopes of Himalayas. (Tekule et al. 2018).

However, feeding an artificial diet also possible for silkworm. The natural silk is obtained from four species of silkworm viz. Mulberry silkworm (Bombyx mori), Tassar silkworm (Antheracea mylitta), Muga silkworm (Antheracea assamensis) and Eri silkworm (Philosemia ricini). Silk is an insect fibre known for its lustre, drape and strength. Due to these unique characteristics, silk is often referred to as the "Queen of Textiles" around the world. India is home to one of the world's oldest civilizations and has made significant contributions to the global textile industry with silk being one of its most notable offerings. India ranks as the second-largest producer of silk globally and is also the largest consumer of this luxurious material. Furthermore, India is unique in that it produces all four commercial varieties of silk: Mulberry, Tassar (both Tropical and Oak), Muga, and Eri. The Indian sericulture industry is distinguished by its high employment potential, low capital requirements and ability to provide profitable income for silk growers (Anonymous, 2020). The sericulture industry provides livelihood opportunities for millions due to its high employment potential low capital requirements and profitable production processes. The industry primarily involves rural-based on-farm and off-farm activities generating significant employment. This potential has caught the attention of planners and policymakers, who recognize sericulture as a key avenue for the socio-economic development of India's largely agrarian economy (Anonymous, 2023).

MATERIAL AND METHODS

The experiment was conducted in a rearing house at the Sericulture Laboratory Department of Entomology, Post graduate Institute, Dr. P.D.K.V., Akola, during

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September to October 2024-25 to study the biological traits of bivoltine silkworm hybrids on G-4 Variety of Mulberry. The experiment was conducted in Completely Randomized Design with seven treatments and three Replication.

Silkworm Hybrids

FC1 X FC2

FC2 X FC1

TT56 X TT21

TT21 X TT56

CSR16 X S8

S8 X CSR16

SK6 × SK7

The improved technology of silkworm rearing adapted in the present investigation was described by Krishnaswami (1978).

Observations: Observations were taken on following parameters on ten randomly selected cocoons of silkworm hybrids from each replication of each treatment.

1. Fecundity (no.): The fecundity of each race was computed by taking number of eggs laid by female of each race after mating.

2. Hatching percentage (%)

$$\text{Hatching (\%)} = \frac{\text{No. of hatched eggs}}{\text{Total no. of eggs}} \times 100$$

3. Larval duration (days): The total larval period was measured by recording the period from hatching to the onset of spinning.

4. Moth emergence (%): The observations on the number of moths emerged from cocoon was recorded and it was expressed in percentage.

$$\text{Moth emergence (\%)} = \frac{\text{Number of moths emerged}}{\text{Total no. of cocoons}} \times 100$$

5. Pupal duration (days): The total pupal period was measured by recording period from spinning to the emergence of moth.

RESULT AND DISCUSSION

This research aimed to assess the profound effects of feeding the highly regarded mulberry variety G-4 on the biological traits of various silkworm hybrids. The compelling findings from this study are comprehensively presented in this research under the following headings.

Fecundity (no.) : The highest fecundity rate was observed in the hybrid FC1X FC2 (543.49). This was followed by the hybrid FC2 X FC1 (542.94) was statistically comparable to the hybrid TT21 X TT56 (516.70). The next highest fecundity rate was found in the hybrid TT56 X TT21 (510.84). The hybrid CSR16 X S8 (496.86) was similar to the rate for hybrid S8 X CSR16 (496.86). The lowest fecundity rate was observed in the hybrid SK6 × SK7 (479.63). Trilekha et al. (2024) recorded a fecundity rate of 597 for the hybrid FC2 × FC1. Similar findings were reported by Mele (2023) and Khaire (2023) who noted fecundity rates of 564.22 and 569.73 respectively, for the same hybrid FC1 × FC2 in their experiments.

Hatching percentage (%) : The highest hatching rate was found in the hybrid CSR16 X S8 (97.01%). This was statistically comparable to the hybrid FC1 X FC2 (95.69 %) and the hybrid S8 X CSR16 (94.52%). The next best hybrid was SK6 × SK7 (94.38%), followed closely by TT21 X TT56 (94.31%), both of which were statistically similar. Hybrid TT56 X TT21 recorded a hatching percentage of 93.98%, while FC2 X FC1 (93.77%) making them the hybrids with the lowest hatching percentage. These results align with the findings of Bobade et al. (2019), who reported the highest hatching rate of 97.48% in hybrid S8 X CSR16. Additionally, Mele (2023) noted a hatching percentage of 97.18 % in hybrid FC1 X FC2, which is consistent with the results presented above.

Larval duration (days) : The shortest larval duration was observed in the hybrid CSR16 X S8 (22.61 days) making it the superior hybrid compared to the others tested. The next best hybrid was SK6 × SK7 (23.26 days) which was comparable to several other hybrids, including TT21 X TT56 (23.44 days), FC2 X FC1 (23.75 days) and S8 X CSR16 (23.83 days). Following that, the hybrid TT56 X TT21 (24.03 days) which was similar to the hybrid FC1 X FC2 (24.75 days). The results of this investigation align with findings by Bobade et al. (2019), who reported a minimum

larval duration of 22.94 days for hybrid S8 X CSR16. Maske et al. (2021), who reported a minimum larval duration of 22.10 days. Mele (2023) also recorded larval durations of 22.92 days for hybrid S8 X CSR16 and 23.95 days for hybrid CSR16 X S8.

Moth emergence (%): The highest percentage of moth emergence recorded in the hybrid CSR16 X S8 (96.41%) which was statistically comparable to several other hybrids. These included SK6 × SK7 (95.91%), FC1 X FC2 (95.87%) and S8 X CSR16 (95.26%). The next best hybrid was TT56 X TT21 (94.77%) which showed a similar performance to TT21 X TT56 (92.74%) and FC2 X FC1 (91.38%). These two hybrids were noted for having the lowest moth emergence rates. These findings align with the research conducted by Khaire (2023), who reported a moth emergence rate of 96.43% for the hybrid S8 X CSR16 and observed a rate of 94.27% for the hybrid CSR16 X S8. Similar results were also noted by Pawar (2024) and Sonone (2024).

Pupal duration (days) : The shortest pupal duration was observed in CSR16 X S8 (9.94 days) which was statistically similar to the hybrid SK6 × SK7 (10.17 days) Both hybrids outperformed the other hybrids tested. The hybrid TT56 X TT21 (10.30 days) was statistically comparable to hybrid FC2 X FC1(10.60 days). The longest pupal durations were observed in hybrids TT21 X TT56 (11.09 days), S8 X CSR16 (11.50 days) and FC1 X FC2 (11.80 days). Similar findings were reported by Bobade et al. (2019), who noted a minimum pupal duration of 9.92 days for the hybrid S8 X CSR16. Maske et al. (2021) reported a minimum Pupal duration of 10.38 days. Mele (2023) also observed pupal durations of 10 days for hybrid S8 X CSR16 (10.19 days). Additional support for these findings was provided by the research of Pawar (2024) and Sonone (2024).

Conclusion:

Among all the seven hybrids used for rearing, hybrid CSR16 X S8 showed the best results for larval duration (22.61 days), pupal duration (9.94 days), egg hatching percentage (97.01%), moth emergence percentage (96.41%) and for fecundity (543.49), hybrid FC1 X F2 shows the best result. Based on biological and overall performance, it can be concluded that the bivoltine

Treatments	Larval duration (Days)	Fecundity	Egg Hatching %	Pupal duration (Days)	Moth Emergence %
FC1 × FC2	24.75	543.49	95.69(78.09)	11.80	95.87 (77.57)
FC2 × FC1	23.75	542.94	93.77(75.58)	10.60	91.38 (72.95)
TT56 X TT21	24.03	510.84	93.98(75.82)	10.30	94.77 (76.83)
TT21 × TT56	23.44	516.70	94.31(76.31)	11.09	92.74 (74.53)
CSR16 X S8	22.61	524.61	97.01(80.09)	9.94	96.41 (79.19)
S8 X CSR16	23.83	496.86	94.52(76.49)	11.50	95.26 (77.54)
SK6 × SK7	23.26	479.63	94.38(76.32)	10.17	95.91 (78.54)
SE (m) ±	0.44	3.11	0.83	0.21	1.19
CD at 5%	1.32	9.42	2.52	0.65	3.61

*Figures in parentheses indicate arc sin transformed values.

hybrid CSR16 X S8 reared on mulberry variety G-4 was found superior to all other hybrids tested under Vidarbha conditions.

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Impact of Rainfall on Physiological Quality and Seed Health of Soybean Seed

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ABSTRACT

Soybean (*Glycine max* L. Merrill) is a globally important crop, with seed quality and yield highly sensitive to environmental conditions, particularly rainfall during seed maturation. This study evaluated the effects of rainfall at physiological maturity on seed quality and health in three soybean cultivars (JS 335; AMS 1001, and JS 9305) using a randomized block design with three replications. Rainfall was simulated at three levels: no rainfall, up to 200 mm, and above 200 mm. Key parameters assessed included seed moisture content, 100-seed weight, germination percentage, vigour indices, yield, and fungal infection rates. Results indicated that rainfall at maturity significantly reduced seed quality and yield. The greatest yield loss was recorded in JS 335 (146.8 kg ha^{-1}), followed by JS 9305 (130.6 kg ha^{-1}) and AMS 1001 (115.5 kg ha^{-1}). Crops unexposed to rainfall produced 9 per cent and 17 per cent higher yields than those exposed to 100 mm and 200 mm of rainfall, respectively. Among the cultivars, AMS 1001exhibited the highest seed quality, with a germination rate of 79.8 per cent, a 100-seed weight of 12.2 g, strong vigour indices and the lowest fungal infection rate (24%). Economic losses were also greater under 200 mm of rainfall (Rs. 8,644 ha^{-1}) than 100 mm (Rs. 7,523 ha^{-1}), with JS 335 suffering the highest losses. The study underscores the importance of harvesting at physiological maturity and maintaining seed moisture below 12 per cent for optimal storage and seed quality preservation. AMS 1001 emerged as the most resilient cultivar under rain-affected conditions, while JS 335 was most vulnerable to fungal infections. These findings emphasize the critical role of timely harvest and appropriate cultivar selection in minimizing the negative impacts of rainfall on soybean seed quality and productivity.

Soybean (*Glycine max* L. Merrill) is one of the most cultivated crops in the world, holding great importance in the Indian economy. Soybeans have quickly become a major crop in Mississippi agricultural systems, expanding into areas previously used for cotton, corn, small grains, and others. The development of soybean crops is linked to new technologies, especially those related to producing high-quality seeds that are free of pathogens and capable of developing high-vigor seedlings (Pelúzio *et al*., 2008).

Genetic characteristics and environmental effects during development, harvesting, processing, and storage stages are key factors in the seed viability period, which is highly variable. Seeds exposed to unfavorable conditions in any of these stages may suffer physiological damage that can impair seed quality, and the degree of damage varies depending on genetic factors and each cultivar (Gris *et al.*, 2010). Many factors influence seed quality. Climate change is a major factor that significantly impacts the quantity and quality of worldwide seed production, such as temperature and rainfall fluctuations. Generally, rainfall during vegetative growth enhances yield, but heavy rainfall during seed development and maturation results in poor seed quality (Thomson, 1979; Tu *et al*., 1988; Olivares *et al*., 2009). However, due to various reasons, it is not always possible to harvest seeds at the optimal time, often leading to delayed harvests (Diniz *et al*., 2013). Delayed harvesting can cause losses in physiological and sanitary seed quality (Henning *et al*., 2011). Mengistu *et al*. (2009) reported that in humid and hot environments, *Phomopsis longicolla* was identified as the primary seed pathogen of soybean. Delayed harvest is also related to prolonged seed exposure to temperature, high relative humidity, and rainfall variations, which negatively affect seed quality. Therefore, limited research has been conducted on the influence of rainfall on the physiological quality and seed health of soybean seeds at maturity. Consequently, research on this topic is vital for safeguarding soybean production against climate change challenges and ensuring the availability of high-quality seeds for future generations. Accordingly, the study was carried out to examine the effect of rainfall on seed quality at the pre-harvest stage, providing valuable insights into how rainfall impacts pre-harvest soybean

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seed quality, leading to improved management practices and reduced yield losses.

MATERIAL AND METHODS

The experiment was conducted at the Seed Technology Research Unit, Dr. PDKV, Akola. It used a randomized block design with three replications and a 3 x 3 factorial arrangement, evaluating three cultivars: JS 335, AMS 1001 and JS 9305, and three harvest times: at the harvest stage, during harvest and up to 200 mm rainfall, and during harvest and above 200 mm rainfall. Natural rain simulations were utilized for the experiment. The plots consisted of six rows, each 12 meters long, with spacing of 0.5 m between rows and 20 seeds meter^{-1}. To investigate how rainfall during harvesting affected seed quality, measurements of seed germination, vigor index I and II, and seed yield were taken. Seeds were harvested, dried at room temperature to approximately 12 per cent moisture content, and then tested for 100 seed weight, seed health status (insect damage), germinability, and vigor (ISTA, 2009). Additionally, seed yield was recorded.

RESULT AND DISCUSSION

The impact of rain at maturity on the physiological quality and seed health of soybean seed is shown in Table 1 and 2, while Figures 1 and 2 display the corresponding rainfall patterns. Rainfall at maturity negatively affected various seed quality parameters, including yield,

Table 1. Effect of rain at maturity on yield loss (Pooled data of 2021-22, 2022-23 and 2023-24)

Treatment	Actual yield (kg ha^{-1})	Yield loss (kg ha^{-1})	Total Yield (kg ha^{-1})	% loss over		Monetary loss (Rs ha^{-1})
				Actual yield	Total yield	
Factor A: Rainfall at maturity						
No rain Touch (T_1)	1341	56.7	1401	4.51	4.30	2725
				(12.15)	(11.87)	
Rain Touch (T_2) (upto 100 mm rainfall)	1219	152.3	1383	15.27	13.0	7523
				(22.91)	(21.08)	
Rain Touch (T_3) (upto 200 mm rainfall)	1113	184.0	1301	20.18	16.28	8644
				(26.61)	(23.75)	
SE (m) $\pm$	16	4	15	0.40	0.34	218
CD 5%	47	13	46	1.22	1.05	658
Factor B: Variety						
AMS 1001 (V_1)	1295	115.5	1420	10.74	9.41	5745
				(18.43)	(17.28)	
JS 335 (V_2)	1175	146.8	1326	15.72	12.83	6937
				(22.47)	(20.32)	
JS 9305 (V_3)	1203	130.6	1338	13.49	11.35	6211
				(20.78)	(19.09)	
SE (m) $\pm$	16	4	15	0.40	0.34	218
CD 5%	47	13	46	1.22	1.05	658
Interaction						
SE (m) $\pm$	27	7	26	0.69	0.60	377
CD 5%	-	-	-	-	-	-

( ) Figures in parenthesis are arcsin values.

(V_1-AMS1001, V_2-JS 335, V_3-JS9305, T_1-Without rain touch, T_2-Rain touch: upto 100mm, T_2-Rain touch: upto 200mm)

Table 2. Effect of rain at maturity on physiological quality and seed health of soybean seed (Pooled data of 2021-22, 2022-23 and 2023-24)

Treatment	Germination (%)	Fungus infection (%)	100 seed wt. (g)	Vigour Index - I	Vigour Index - II	Moisture content (%)
Treatment						
No rain Touch (T_1)	85.5	(25.53)	11.6	2455	35.50	11.46
	(67.8)	18.97				
Rain Touch (T_2) (up to 100 mm rainfall)	74.3	41.48	11.8	1792	28.88	11.61
	(59.7)	(39.79)				
Rain Touch (T_3) (up to 200 mm rainfall)	66.2	52.13	12.1	1342	24.21	12.14
	(54.4)	(46.23)				
SE (m) ±	0.52	0.90	0.21	43.9	0.64	0.19
CD at 5%	1.57	2.74	-	132.7	1.95	-
Variety						
AMS 1001 (V_1)	79.8	24.00	12.2	2154	33.76	12.01
	(63.8)	(29.03)				
JS 335 (V_2)	74.8	47.07	11.5	1761	28.63	11.62
	(60.1)	(42.99)				
JS 9305 (V_3)	71.3	41.49	11.7	1674	26.20	11.58
	(57.9)	(39.53)				
SE (m) ±	0.52	0.90	0.21	43.9	0.64	0.19
CD at 5%	1.57	2.74	-	132.7	1.95	-
Interactions(VxT)						
V_1T_1	89.67	17.25	11.91	2773	40.41	11.84
	(71.2)	(24.24)				
V_1T_2	80.92	23.78	12.38	2221	33.56	12.45
	(64.1)	(29.03)				
V_1T_3	69.22	31.00	12.55	1470	27.30	11.31
	(56.1)	(33.81)				
V_2T_1	83.39	21.11	11.13	2331	33.26	11.47
	(65.9)	(27.11)				
V_2T_2	74.36	53.36	11.58	1655	28.73	12.10
	(59.8)	(46.96)				
V_2T_3	66.56	66.75	12.01	1299	23.92	11.36
	(54.7)	(54.89)				
V_3T_1	83.28	18.56	11.75	2261	32.83	11.53
	(66.2)	(25.24)				
V_3T_2	67.36	47.31	11.65	1502	24.37	11.85
	(55.1)	(43.37)				
V_3T_3	63.31	58.64	11.88	1260	21.43	11.73
	(52.5)	(50.00)				
SE (m) ±	0.90	1.57	0.37	76.0	1.12	0.32
CD at 5%	2.73	4.75	-	230.0	NS	-

( ) Figures in parenthesis are arcsin values.

(V_1-AMS1001, V_2-JS 335, V_3-JS9305, T_1-Without rain touch, T_2-Rain touch: upto 100mm, T_2-Rain touch: upto 200mm)

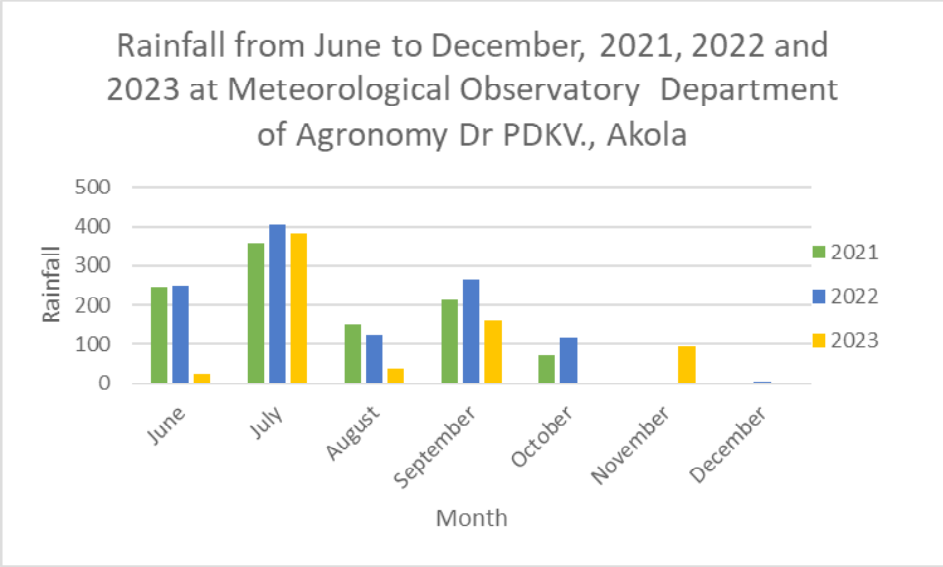

Fig. 1 Rainfall data of PDKV campus location

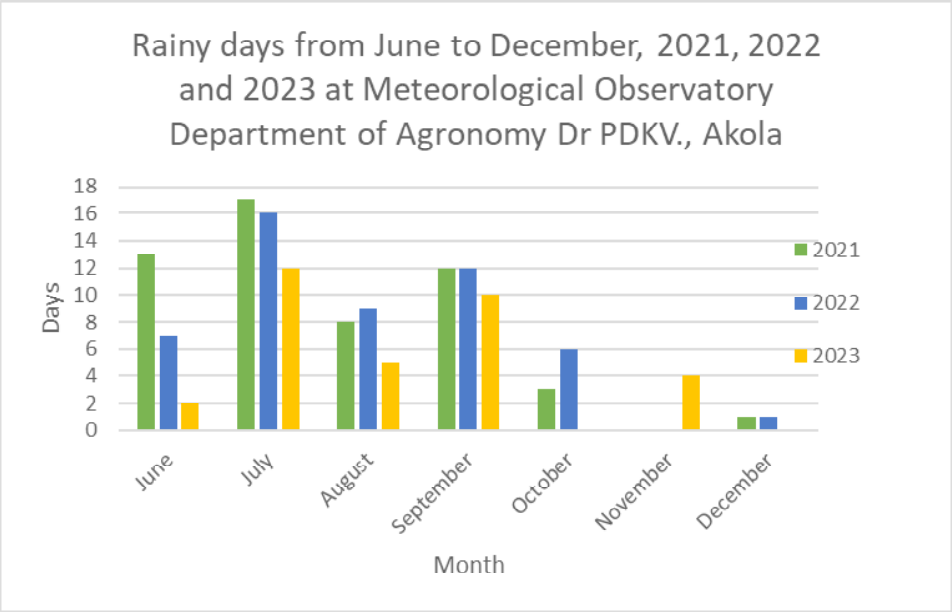

Fig. 2 . Rainy days of PDKV campus location

germination, fungus infection, and vigor index. The highest yield loss of 146.8 kg ha^{-1} was observed in JS 335, followed by JS 9305 (130.6 kg ha^{-1}) and AMS 1001 (115.5 kg ha^{-1}).

Significant findings emerged from this investigation. The soybean crop not subjected to rainfall at maturity showed a higher seed yield of 1341 kg ha^{-1} compared to those exposed to rainfall. Specifically, the treatment without rainfall recorded 9 per cent and 17 per cent higher yields than those with 100mm and 200mm of rainfall at maturity, respectively.

Furthermore, the variety AMS 1001 showed a higher seed yield (1295 kg ha^{-1}) compared to JS-335 (1175 kg ha^{-1}) and JS 9305 (1203 kg ha^{-1}), with increases of 9 per cent and 7 per cent, respectively.

Regarding monetary loss, crops receiving 200mm rainfall at maturity incurred a significantly higher loss (Rs. 8644 ha^{-1}) compared to those with 100mm rainfall (Rs. 7523 ha^{-1}). Additionally, among the varieties, JS 335 experienced

the highest monetary loss (Rs. 6937 ha^{-1}) compared to JS 9305 (Rs. 6211 ha^{-1}) and AMS 1001 (Rs. 5745 ha^{-1}).

AMS 1001 also demonstrated superior seed quality parameters, such as germination percentage (79.8 %), 100 seed weight (12.2g), seed vigor I (2154) and seed vigor II (33.76), exceeding JS 9305 and JS 335. Additionally, AMS 1001 exhibited the lowest susceptibility to fungus infection (24 %) among the three varieties.

Compared to non-rain-touch seeds, rain-touch seeds showed poorer seed quality parameters. Rain at maturity caused higher yield loss (184 kg ha^{-1}) than in seeds without rain touch (56.7 kg ha^{-1}). Germination percentage remained at 85.5 per cent without rain touch but dropped to 66.2 per cent with rain touch. Fungus infection was significantly higher in rain-touch seeds (52.13%) than in non-rain-touch seeds (18.97%).

In general, AMS 1001 proved to be the most suitable variety for maintaining seed quality parameters even after exposure to rain at maturity.

CONCLUSION

The present study concludes that harvesting soybean at its physiological maturity is essential for achieving higher yields with quality seeds. The soybean variety AMS 1001, which maintains better seed quality parameters even after preharvest rain exposure, offers a valuable trait for farmers especially in regions prone to untimely rainfall during the harvest season. Conversely, soybean variety JS 335 shows increased susceptibility to fungal infection following rainfall during harvest. Additionally, keeping moisture levels below 12 per cent is advisable for the safe and long-term storage of soybean.

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Effect of Salt Treated Soybean Straw Feeding on Performance of Lactating Cows

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ABSTRACT

Present investigation was planned at Livestock Instructional Farm, Deptt. of AHDS, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, for a period of 120 days per trial and 03 trials were planned and conducted during the year 2022-23 and 2023-24 (I trial July.2022 to Oct.2022, II trial March,2023 to June, 2023. Oct. 2024 to Jan. 2024). For every trial 20 mid lactation stage non-descript cows were selected and randomly divided into four groups, on the basis of nearness in their average milk production and date of calving and conduct as T_1 (Dry roughages (Sorghum straw) ad lib.), T_2 (Dry roughages (Untreated Soybean straw) ad lib.), T_3 (Dry roughages (2% salt treated soybean straw) ad lib.), T_4 (Dry roughages (4% salt treated soybean straw) ad lib.). In addition to this for all experimental animals of all treatments 5 kg Green roughages + 3 kg Concentrate were provided during the experiment. The main objective was to utilize non-conventional Soybean straw as protein source roughage in the ration of lactating cows to find out its effect on production and economics of production.

On the basis of results obtained in the present investigation, it is concluded that, Enrichment with salt treatment increases the softness and acceptability of SBS in cows, average DMI/ 100 kg BW was 3.09, 2.51, 3.05 and 2.89 kg in T_1, T_2, T_3 and T_4 groups, respectively. Statistically significant increase in milk production over T_2(USBS) and control i.e. T_3 was superior followed by T_4 and T_1, but T_3 and T_4 results were at par with each other. Average weekly (per day) milk production was recorded as 36.34 kg and per day 5.19 kg 28.39 and 4.06, 37.13(5.30) and 36.87 (5.27) kg for treatment T_1 (Control), T_2 (USBS), T_3(2%STSBS) and T_3(4%STSBS) respectively. The daily cost of feeding/ cow was Rs. 141.40/-, 121.55, 127.67/- and 128.48/- and cost of feeding per lit of milk was recorded as 27.25/-, 29.94/-, 24.09/- and 24.38/- under T_1, T_2, T_3 and T_4 groups, respectively.

Dairying is a sustainable activity for bringing out socio- economic change for rural population. The focus on dairy development in the country has given fruitful results where a milk deficient country before few year ago, has achieved a target of 181.7 million tons of milk production during 2018-19 with capita^{-1} availability of 394 and 266 g milk day^{-1} in India and Maharashtra, respectively (20th Livestock Census). During 2023-24 the land under sowing of soybean crop was up to 47.80 Lakh hectares and 17.66 Lakh hectare in Maharashtra and Vidarbha, respectively, indicating the popularity to these non-conventional crops among farmers (Annual report of GCMMF of 2023-24). Considering same area near about 70 Million Quintal soybeans straw is available in Vidarbha region. In addition to that soybean straw is a leguminous crop and its straw is superior in protein content as compared to cereal crop straws like sorghum straw, wheat straw and rice straw. Hence, soybean crop residue seems to be emerging alternative roughage to sorghum and other cereal straws for animal feeding. But as per the growing habit of soybean all the leaves were shredded at the time of harvesting, only stems and pod kernels were present in the straw, further it contain about 17 per cent lignin, which make straw more hard and course, these affects the intake, palatability, softness of straw and deficit in intake and digestibility affects negatively on health and production of animal.

Therefore present investigation was planned at Livestock Instructional Farm, Deptt. of AHDS, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, for a period of 120 days per trial and 03 trials were planned and conducted to utilize non-conventional Soybean straw as protein source roughage in the ration of lactating cows to find out its effect on DMI, milk production and quality.

MATERIAL AND METHODS

Total 03 trials were conducted in the present investigation (I trial July.2022 to Oct.2022, II trial March,

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2023 to June, 2023. Oct. 2024 to Jan. 2024). For every trial 20 mid lactation stage non-descript cows were selected from the herd. These cows were randomly divided into four groups, on the basis of nearness in their average milk production and date of calving. Experiment was conducted continuously as per calving and availability of milking animals. For every trial 20 mid lactation stage non-descript cows were selected and randomly divided into four groups, on the basis of nearness in their average milk production and date of calving and conduct as T_1 (Dry roughages (Sorghum straw) ad lib.), T_2 (Dry roughages (Untreated Soybean straw) ad lib.), T_3 (Dry roughages (2% salt treated soybean straw) ad lib.), T_4 (Dry roughages (4% salt treated soybean straw) ad lib.). In addition to this for all experimental animals of all treatments 5 kg Green roughages + 3 kg Concentrate were provided during the experiment. DMI and Milk yield was recorded both in the morning and evening for whole experimental period. Milk samples were drawn for analysis from morning and evening once every week throughout the experimental period. Economics of feeding was compared with in treatments after completion of studies on comparative basis for body weight change of cows and receipt earned from milk. Data obtained in the present investigation was statistically analyzed by applying RBD (Amble, 1975).

RESULT AND DISCUSSION

Average intake of different feeds/day/cow (kg)

The intakes of different feeds are directly related to supply of different nutrients to animal body and subsequently its influence on the performance of the animal. In view of this the intake of different feeds consisting Jowar and Soybean straws, Green Hybrid Napier and concentrate under different treatments are recorded in order to know the response of cows to nonconventional SBS straw. The data in this regard are tabulated in Table 1.

It is evident from Table 1, that the cows were offered 8 kg of Jowar straw, untreated and treated SBS straw under T_1, T_2, T_3 and T_4 groups. However it was it was noticed that there were differences in refusal of straws between the treatments. Maximum refusal (3.10 kg) was noticed in T_2; while the minimum refusal (1.20 kg) was observed in T_1 whereas 1.65 and 1.35 kg left over was noted in T_3 and T_4 groups, respectively. On this basis, the per cent refusal worked out as 15.00, 38.75, 20.63 and 16.87 per cent in T_1, T_2, T_3 and T_4 groups, respectively. This trend did indicate that SBS was palatable to cows. Table 3 presents daily feed /straw intakes over the experimental period of 17 weeks. It was observed that there was a significant difference in straw intake between the treatments. Amongst the treatments, consumption of SBS was recorded as, T_2 untreated SBS (4.90 kg cow^{-1}), T_3 2 per cent salt treated SBS group (6.35 kg cow^{-1}) and T_4 4 per cent salt treated SBS group (6.65 kg cow^{-1}) in cows. Which indicated more intake by 29.59 per cent and 35.71 per cent in 2 per cent salt treated SBS group (6.35 kg cow^{-1}) and 4 per cent salt treated SBS group over untreated SBS group. These trends therefore did indicate clearly that salt treatment to SBS proved beneficial and effective for increasing acceptability and palatability of fibrous hard textured SBS in cows.

This all feed intake values were compared with the standard values of suggested by ICAR, (1975 and 1985) as well as reported by Jagdish and Neeraj (2008) and observed that nowhere malnutrition was reported in the feeding of experimental animals.

Table 1. Average intake of different feeds/day/cow (kg) (Mean values of 03 trials)

Treatments	Jowar Straw /Soybean straw			Hybrid Napier		Concentrate	Total feed
	Offered	Leftover	Intake	Offered	Intake	Offered	intake
T_1 (Control)	8.00	1.20	6.80	5.00	5.00	3.00	14.80
T_2 (USBS)	8.00	3.10	4.90	5.00	5.00	3.00	12.90
T_3 (2%STSBS)	8.00	1.65	6.35	5.00	5.00	3.00	14.35
T_4 (4%STSBS)	8.00	1.55	6.45	5.00	5.00	3.00	14.45

Average daily dry matter intake per cow in comparison to Feeding Standards

The results of the daily feed intake clearly demonstrated that the cows from all the treatments received the DM in sufficient quantity to fulfill the ICAR feeding norms. However it seems essential to ascertain whether this intake was proportionate to their body weight or otherwise. In view of this the data on DMI was converted to unit body size and are shown in Table 1

It was observed from Table 6, that the average DMI/ 100kg BW was 3.09, 2.51, 3.05 and 2.89 kg in T_1, T_2, T_3 and T_4 groups, respectively. DMI was more in T_1 followed by T_4, T_3 and T_2 groups. Moreover per cent DMI on feeding salt treated SBS was significantly more over that of untreated SBS group. This means enrichment of SBS with salt was advantageous to increase the DMI per unit body size. These results were also supported by the findings of other research workers as, Hency *et al.,* (2024) reported that feeding of 2 per cent salt treated soybean straw increases DMI in the gir cows heifers. Shelke, *et al.,* (2018) also reported that soybean straw treated with 2 per cent urea improves softness, palatability and DMI intake in the lactating cows. Badurdeen *et al.,* (1993) also noted that moistening of rice straw with the solution of 2 per cent common sea salt (sodium chloride) significantly affects the intake and digestibility. In the report posted by Punjab Agriculture University (2023), it is clearly mentioned that salt and urea treatment on straw becomes softer and palatable, due to which the animals ability to eat the straw increases.

Effect on milk production of cows

Results of all three trials pooled means shows that average weekly milk production of control group cows was 36.34 and per day 5.19 kg was reduced up to 28.39 and 4.06 kg, respectively, that indicates adverse effect of untreated soybean straw to the cows that might be due to coarse, hardness of straw, less DMI, less Water Intake and less digestibility of feed. On the other hand salt treatment on soybean straw leads to increase in softness, DMI, Water intake and digestibility of feed, which results in increased average weekly and per day milk production.

The mean values as 37.13, 36.87 and 5.30, 5.27 kg. respectively were recorded for treatment T_3(2%STSBS) and T_3(4%STSBS). It shows statistically significant

Table 2. Average DMI kg/day of cows in comparison to feeding standards. (Mean values of 03 trials)

Treatment	BW (kg)	DMI (kg)	DMI requirement (2.5 kg% BW)	Per cent (excess/ deficit) intake	DMI/100kg BW
T_1 (Control)	311.8	9.64	7.80	23.59	3.09
T_2 (USBS)	315.2	7.91	7.88	0.38	2.51
T_3(2%STSBS)	310.8	9.47	7.77	21.88	3.05
T_4(4%STSBS)	320.4	9.27	8.01	15.73	2.89

Table 3. Effect of salt treated soybean straw feeding on milk production of cows under different treatment.

(Mean values of 03 trials)

Treatments	Milk Production (kg/ week) for 03 trials			Pooled mean Weekly milk production	Per day avr. milk production
	I	II	III		
T_1 (Control)	36.50	35.76	36.75	36.34	5.19
T_2 (USBS)	28.67	27.99	28.52	28.39	4.06
T_3(2%STSBS)	37.18	36.85	37.35	37.13	5.30
T_4(4%STSBS)	36.95	36.42	37.25	36.87	5.27
SE(m)±	0.165	0.168	0.169	0.167	0.149
C.D.(P<0.05)	0.506	0.509	0.511	0.508	0.453

increase in milk production over T_2 (USBS) and control i.e. T_3 was superior followed by T_4 and T_1, but T_3 and T_4 results were at par with each other. The results reported by Shelke, *et al.,* (2018) that soybean straw treated with 2 per cent urea increases milk production by 24 to 25 per cent in non-descript lactating cows. In the report posted by Punjab Agriculture University (2023) it is also clearly mentioned that salt and urea treatment on straw is beneficial for increasing milk production. These results are in agreement with the present investigations observations.

Economics of feeding untreated and treated soybean straw:

Crop residues are basic component in the ration of cattle. However these residues do not support nutritionally to animals either for maintenance or for production unless supplemented with greens and concentrates.

In reference to above it is expected that inclusion of non-conventional leguminous SBS as a substitute to cereal straw can help to improve nutritive status of the ration as this straw contained practically 2 to 3 times more CP than that of conventional straws. Moreover one can expect improvement in nutritive value of SBS on enrichment with salt treatment and thereby possibility of reduction in the requirement of concentrates. However any new feeding approach must withstand economically and easily available for it's vide application at field level. Considering these views, economics of feeding SBS to lactating cows was worked out and results are tabulated in Table 4.

The results on economics of feeding different feeds revealed that the daily cost of feeding did indicate a wider range between the feeding groups. The daily cost of feeding/cow was Rs. 141.40/-, 121.55, 127.67/- and 128.48/- and cost of feeding lit^{-1} of milk was recorded as 27.25/-, 29.94/-, 24.09/- and 24.38/- under T_1, T_2, T_3 and T_4 groups, respectively. However it appears that one could reduce the expenditure on feeding of the cows to the extent of 11.31 and 11.17 per cent by offering 2 per cent Salt treated (T_3) and 4 per cent Salt treated (T_4) SBS over feeding of untreated SBS. Same results were also reported

Table 4 . Economic of feed cost of the experimental cows under different treatments (pooled mean values of 03 trails)

S. N.	Particular	T_1		T_2		T_3		T_4	
		Qty.	Cost	Qty.	Cost	Qty.	Cost	Qty.	Cost
1	Soybean straw @ 150/- qt Jowar straw @400/-qt.	40.80	16320/-	29.40	4410/-	38.10	5715/-	3870	5805/-
2	Salt @ 4.75/kg	—	—	—	—	76.50	363/-	159.60	758/-
3	Green Hy Napier @ 150/-qt	30.00	1500/-	30.00	1500/-	30.00	1500/-	30.00	1500/-
4	Concentrate (Sugras) @ 25.00/kg	18.00	45000/-	18.00	45000/-	18.00	45000/-	18.00	45000/-
5	Mineral Mixture @ Rs 140 / kg	18	2520/—	18	2520/-	18	2520/-	18	2520/-
6	Processing cost (polythene bags, handling etc)	—	—	—	—	—-	2000/-	—	2000/-
7	Labour charges @320/ per dayX 2LabourX120=76800/4=19500/-	—	19500/-	—	19500/-	—	19500/-	—	19500/-
8	Total cost for five cows for 120 days	84840/-	72930/-	76598/-	77083/-				
9	Total Cost/cow over 120 days	16968/-	14586/-	15320/-	15417/-				
10	Feed cost /day/cow	141.40/-	121.55/-	127.67/-	128.48/-				
11	Milk Prod. (kg/day/cow)	5.19	4.06	5.30	5.27				
12	Milk Cost (@50/- per Kg)	259.5/-	203.00/-	265.00/-	263.50/-				
13	Feed cost/kg Milk Prod.	27.25/-	29.94/-	24.09/-	24.38/-				
14	B:C Ratio	1:1.84	1:1.67	1: 2.08	1:2.05				

by Shelke, *et al.,* (2018) that soybean straw treated with 2 per cent urea increases milk production and decrease cost of production. Report posted by Punjab Agriculture University (2023) also suggest that salt and urea treatment on straw is most cost effective by increasing milk production.

CONCLUSION

On the basis of results obtained in the present investigation, it is concluded that, Leguminous SBS emerged out as alternative non-conventional roughage to replace cereal straws. Enrichment with salt treatment increases the softness and acceptability of SBS in cows, average DMI 100^{-1} kg BW was 3.09, 2.51, 3.05 and 2.89 kg in T_1, T_2, T_3 and T_4 groups, respectively. DMI was more in T_1 followed by T_4, T3 and T2 groups. Statistically significant increase in milk production over T_2 (USBS) and control i.e. T_3 was superior followed by T_4 and T_1 but T_3 and T_4 results were at par with each other. Average weekly (per day) milk production was recorded as 36.34 kg and per day 5.19 kg 28.39 and 4.06, 37.13(5.30) and 36.87 (5.27) kg for treatment T_1 (Control), T_2 (USBS), T_3(2%STSBS) and T_4(4%STSBS), respectively. The daily cost of feeding/ cow was Rs. 141.40/-, 121.55, 127.67/- and 128.48/- and cost of feeding per lit of milk was recorded as 27.25/-, 29.94/-, 24.09/- and 24.38/- under T_1, T_2, T_3 and T_4 groups, respectively. However, it appears that one could reduce the expenditure on feeding of the cows to the extent of 11.31 and 11.17% by offering 2% Salt treated (T_3) and 4% Salt treated (T_4) SBS over feeding of untreated SBS.

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