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Genetic divergence in castor [*Ricinus communis* (L.)]

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ABSTRACT

Mahalanobis D^2 statistics analysis was employed to measure the genetic divergence of 34 genotypes of castor. Six different clusters were formed with a wide range of inter cluster distances (17.17 to 331.75) suggesting considerable diversity among the genotypes. Clustering pattern indicated that geographical distribution could not be taken as sole criterion of genetic diversity. The D^2 analysis revealed that harvest index, oil content, number of capsules/plant and seed yield/plant contributed maximum towards genetic divergence. It was suggested that the geotypes seperated by higher statistical distance could be utilized in hybrid breeding programme as well as for obtaining wide spectrum of variation among the segregates.

Key words : Castor, genetic divergence, D^2 statistics

The choice of the parents is of paramount importance in any breeding programme. Genetic divergence analysis is attempted to identify parents for realizing high heterosis and superior recombination's in segregating generations (Arunachalam, 1981).

The D^2 statistics proposed by Mahalanobis (1936) is one of the potent techniques of estimating genetic divergence based on multivariate analysis and canonical analysis (Moll *et al.*, 1962 and Bhatt and Reddy, 1987). This technique measures the forces of differentiation at two levels, *viz.*, intracluster and intercluster levels and thus helps in the selection of genetically divergent parents for exploitation in hybridization programme. In addition to aiding in the degree of diversification, it also determines the relative contribution of each component character to the total divergence. The genotypes grouped together are less divergent than the ones which are placed in different clusters. The clusters which are separated by the highest statistical distance show the maximum divergence.

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MATERIALS AND METHODS

The experimental material consisting of 34 genotypes of castor were obtained from Research Scientist (Castor), S. D. Agricultural University Sardarkrushinagar. These genotypes were grown in a randomized block design with three replications at Main Castor-Mustard Research Station, S.D. Agricultural University, Sardarkrushinagar (Gujarat). Each genotype was grown in a single row of 12 dibbles, spaced at 90 cm with intra-row spacing of 60 cm. To raise the crop recommended package of practices for irrigated conditions were adopted. The observations were recorded on five randomly selected plants for each treatment and each replication for 12 characters *viz.* days to 50% flowering, days to 50% maturity, plant height, length of main spike, number of nodes up to primary spike, number of branches/plant, number of effective branches/plant, 100 seed weight, harvest index, oil content and seed yield/plant.

The Mahalanobis's D^2 statistics were used to measure the genetic divergence as suggested by Rao (1952). Transformation of original means of various characters (X's) to uncorrected varieties (Y's) was carried out by pivotal condensation as the common dispersion matrix on computer.This made D^2 value as a simple sum of

squares of differences in transformed values for various characters. The generalized distance between any two populations is defined as

$$D^2 = b_1d_1 + b_2d_2 + \ldots\ldots + b_pd_p$$

Where,

$X_1, X_2, X_3 \ldots, X_p$ as a multiple measurements available on each individual, being the different in the mean of the two populations. In terms of variance, the D^2 value is obtained as follow:

$$D^2{}_p = W_{ij}\left(X_i^{-1} - X_i^{-2}\right)\left(X_j^{-1} - X_j^{-2}\right)$$

Where,

W_{ij} = Inverse estimated variance and covariance.

Grouping of the genotypes was done by using Tocher's method (Rao, 1952). The criterion used for the clustering in this method is that, two genotypes belonging to the same cluster should on average show a smaller D^2 values, than those belonging to different clusters.

To start with two genotypes having smallest D^2 values between them were considered, to which a third genotype having a smallest average D^2 value from these genotype was added. Next the nearest fourth genotype was considered and the procedure was continued at a certain stage, when it was felt that inclusion of a genotype results in abrupt increase in the average D^2 of the genotypes (for the cluster), that genotype was not included in the cluster. In the similar way the other clusters were formed. This procedure was continued till all the genotypes were included in one cluster or the other. After the information of clusters, average intra-cluster distance (D) was calculated by using the formula:

$$D = \sqrt{\frac{\sum Di^2}{n}}$$

Where,

$\sum Di^2$ = Sum of distance between all possible combinations of the population included in the cluster,

n = Number of population in a cluster.

The inter-cluster distance was calculated by measuring the distance between cluster-I and II, between cluster-I and III, between II and III and so on. Likewise, one by one cluster was taken and their distances from other clusters were calculated. For graphical presentation average intra and inter-cluster D values were used to obtain mutual relationship between the clusters.

RESULTS AND DISCUSSION

In the present study, Mahalanobis D^2 statistic was computed for all the possible pairs of genotypes in order to assess the genetic diversity present among 34 genotypes of castor studied. The 34 genotypes of castor were grouped in six clusters (Table 1).

Grouping of the genotypes was carried out by following the Tocher's method (Rao, 1952) with assumption that the genotypes within the cluster have smaller D^2 values among themselves than those from groups belonging to different clusters. The cluster V was the smallest having only two genotypes from Kutch and Surendranagar. Cluster I was the biggest cluster with 11 genotypes from Tamilnadu, Jamnagar, Vijapur, Kutch, Sardarkrushinagar (Gujarat and Uttaranchal) followed by cluster II with 8 genotypes form Hyderabad (Andhra Pradesh) and Kutch (Gujarat) and cluster III with six genotypes form Tamilnadu, Uttaranchal, Junagadh, Kutch, Sardarkrushinagar (Gujarat). The clustering pattern showed that the genotypes of different geographical areas were clubbed in one cluster and also the genotypes belonging to same geographical area were grouped in different clusters indicating that there was no formal relationship between geographical diversity and genetic diversity. Murty and Arunachalam (1981) have stated that genetic drift and selection in different environments could cause greater diversity than geographic distance. The absence of parallelism between geographic distribution and genetic diversity in the present study is in accordance to the findings of Sevagaperumal *et al.* (2001), Anjani *et al.* (2002) and Patel *et al.* (2004).

The D^2 statistic estimated for 34 accessions for 12 characters showed that the generalized distance ($\sqrt{D^2}$) within clusters ranged from 0.00 to 40.90 which was an indicator of diversity available in the material evaluated. On the bases of D^2 values, six clusters were formed from 34 genotypes. The inter and intra cluster distances (Mahalanobis Euclidean Distance-not to scale) amongst six clusters are diagrammatically presented in Fig.1.

Three clusters *viz.*, cluster IV (with 4 accessions), cluster V (with 2 accessions) and cluster III (with 3 accessions) had least intra cluster distance (0.00) indicating that the genotypes included within these

Table 1 Composition of different clusters based on D^2 values of 34 genotypes of castor

Clusters	Number of genotypes	Name of genotypes	Origin/Source
I	11	TMV-2-6, JM-6, VH-38-2, VH-58-2-7, VH-71-2-3,EC-97708,EC-97709, SPS-47-8, SPS-57-8, SKI-147, T-3.	Tamilnadu, Jamnagar, Vijapur, Thailand, Kutch, Sardarkrushinagar, Uttaranchal.
II	8	HC-7, SPS-38-7, SPS-76-7, SPS-37-6, SPS-43-9, SPS-31-2, SPS-38-8, OTC -30-10.	Hyderabad, Kutch.
III	6	JI-23, ROSY, SPS-71-2, SKI-280, T-9, GC-2.	Junagadh, Tamilnadu, Kutch, Sardarkrushinagar, Uttaranchal.
IV	4	SKI-283, SKI-288, SKI-293, T-4.	Sardarkrushinagar, Uttaranchal.
V	2	OTC-30-5, SH-72.	Kutch, Sardarkrushinagar.
VI	3	GC-3, GCH-5, GCH-7.	Sardarkrushinagar.

Table 2 Average intra and inter-cluster distances, D ($D = \sqrt{D^2}$) values in castor

Cluster	I	II	III	IV	V	VI
I	25.68	48.83	63.21	43.79	36.94	234.22
II		34.58	75.85	83.96	82.61	305.17
III			40.90	89.59	96.50	331.75
IV				0.00	17.27	113.36
V					0.00	138.27
VI						0.00

Table 3 Cluster means for twelve characters in castor

Cluster	Days to 50% flowering	Days to 50% maturity	Plant height (cm)	Length of main spike (cm)	Nodes up to primary spike	Capsule/ plant	Branches/ plant	Effective branches/ plant	100 Seed weight (g)	Harvest index (%)	Oil content (%)	Seed yield/ plant (g)
I	66.67	131.36	71.30	45.42	88.66	44.18	3.53	2.74	30.67	15.68	40.54	76.46
II	66.42	130.75	90.67	52.13	18.82	64.50	3.19	2.26	33.46	18.23	49.13	97.17
III	66.17	130.05	75.83	49.83	17.16	45.61	3.49	3.13	35.11	24.38	45.23	118.44
IV	66.75	130.50	88.83	56.50	18.48	89.25	3.50	2.65	36.08	30.69	45.29	162.67
V	66.17	130.33	101.33	62.00	20.27	108.00	3.17	2.17	32.67	17.58	45.58	83.17
VI	64.56	128.89	75.67	54.78	17.93	58.11	5.74	4.66	38.00	33.11	47.99	191.11

Table 4 Per cent contribution of different characters to total genetic divergence in castor

Sr.No.	Character	Number of times character ranked first	Per centContribution (%)
1	Days to 50% flowering	0.01	0.00
2	Days to 50% maturity	2	0.36
3	Plant height	1	0.18
4	Length of main spike	6	1.07
5	Number of nodes up to primary spike	5	0.89
6	Number of capsule/plant	94	16.76
7	Number of branches/plant	34	6.06
8	Number of effective branches/plant	4	0.71
9	100 Seed weight	24	4.28
10	Harvest index	169	30.12
11	Oil content	160	28.52
12	Seed yield/plant	62	11.05

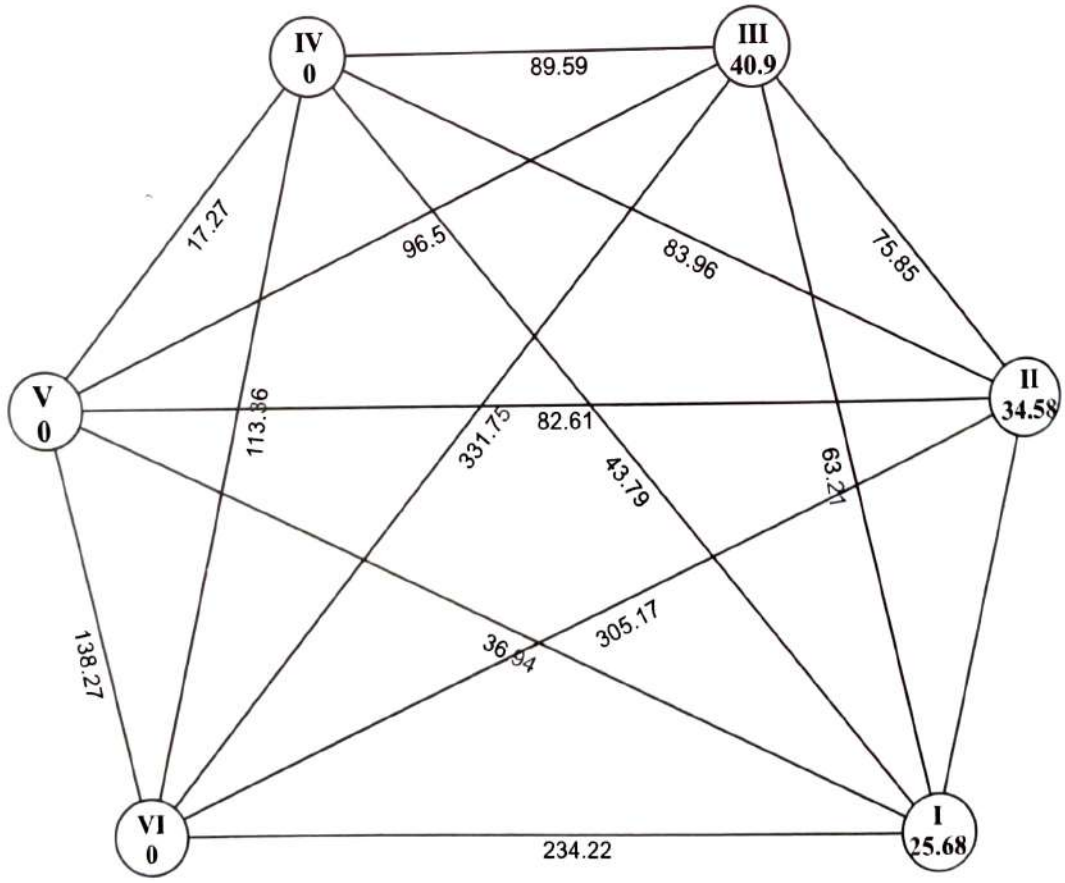

Fig. 1 Mahanobis Euclidean distance diagram

three clusters were not diverse from each other (Table 2). The intra cluster distance was highest for cluster III (with six genotypes) followed by cluster II (with eight genotypes) and cluster I (with eleven genotypes). The high intra cluster distance indicated the wider genetic diversity among the genotypes included within these clusters. In general the inter cluster distances were higher than the intra cluster distances. The highest inter cluster distance was recorded in cluster III and VI (331.75) followed by cluster II and VI (305.17) and cluster I and VI (234.22). The genotypes belonging to the clusters separated by high statistical distance could be used in heterosis breeding programme and also for obtaining wide spectrum variation among the segregates.

The clustering pattern could be utilized in deciding the cross combinations which may generate the highest possible variability for the traits. The cluster means for 12 characters are given in (Table 3). The genotypes with high values of any cluster can be used either for direct adoption or for hybridization or for further selection and improvement. In the presence study cluster I was top ranking for dwarf plant height while cluster IV for higher length of the main spike, cluster V for higher number of capsules/plant and cluster II for higher oil content. It would be worthwhile to select the genotypes from these clusters for hybridization programme for genetic improvement. Since cluster VI included the three released variety/ hybrids *viz.*, GC-3, GCH-5 and GCH-7 this cluster had high cluster mean for most of the yield components *viz.*, branches/plant, effective branches/plant, 100 seed weight, harvest index and seed yield/plant.

It is well established fact that more the genetically diverse parents used in hybridization programme, greater will be the chances of obtaining high heterotic hybrids and broad spectrum variability in segregating generations (Arunachalam, 1981). It has also been observed that the most productive hybrids may come from high yielding parents with a genetic diversity. Therefore, in the present investigation based upon high yielding genotypes and large inter cluster distances, it is advisable to attempt crossing of the accessions which may lead to broad spectrum of desirable genetic variability for yield improvement in castor.

The components of D^2 due to each character were ranked I being assigned to the highest value. The total of these ranks over all possible n (n-1)/2 = 561 combinations would provide indirect information about the order of priority in terms of per cent contribution of the character to the total divergence. It was observed that harvest index (30.12%) followed by oil content (28.52%), number of capsules/plant (16.76%) and seed yield/plant (11.05%) were the main contributors towards the total divergence (Table 4). The remaining characters like number of branches/plant (6.06%) and 100 seed weight (4.28%) had moderate contribution where the rest of the characters had relatively lower contribution towards the total genetic divergence.

CONCLUSION

Genetic divergence was studied in 34 genotypes of castor performing Mahalonobis D^2 analysis. These genotypes were grouped in six clusters. The intra cluster distance was as minimum as 0.0 (cluster IV, V and VI) to 40.9 (cluster III). The inter cluster distance 331.75 (between III and VI). The clustering pattern suggested that the geographical diversity was not an indicator of genetic diversity. In terms of per cent divergence, it was revealed that harvest index (30.12%) followed by oil content (28.52%), number of capsules /plant (16.76%) and seed yield (11.05%) contributed substancially. It was suggested that the geotypes seperated by higher statistical distance could be utilized in hybrid breeding programme as well as for obtaining wide spectrum of variation among the segregates.

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Stability analysis for yield and its contributing traits in Indian mustard [*Brassica juncea* (L). Czern & Coss] under variable environments

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ABSTRACT

Stability analysis was carried out with fourteen elite genotypes of Indian mustard [*Brassica juncea* (L). Czern & Coss] including four check *viz.*, NRCHB 506, Kranti (National check) and GM 3, GDM 4 (State check) over five different environments (Sardarkrushinagar, Junagadh, Amreli, Vijapur and Derol) of Gujarat to identify phenotipically stable genotypes that could perform more or less uniformly under different environmental conditions for various economic traits. Analysis of variance revealed that the genotypes exhibited significant genetic variability for all the traits except days to maturity, seeds per siliquae and seed yield per plot. Genotype x Environment interaction was observed to be significant for all the characters. Environment (linear) interaction component was also significant for all the traits studied, while the linear component of environment interaction was significant for length of siliquae and number of siliquae per plant. The variance due to pooled deviation (non-linear) was highly significant for all the traits except number of siliquae per plant which reflect considerable genetic diversity in the material. In the present investigation genotypes SKM 1219 and SKM 1428 were stable for days to flowering as well as maturity. Genotypes, SKM 1414, SKM 1404 and SKM 1219 for length of siliquae; Kranti, SKM 1413 and SKM 1219 for seeds per siliquae; SKM 1428 for test weight were found to be stable under varying environment conditions.

Key words : Mustard, stability, G x E Interaction, seed yield

Rapeseed-mustard is one of the important edible oil plants needed for human consumption. Indian mustard belong to family *cruciferae* and alone covers 70% of the area among the different *Brassica* spp. In India this crop is grown under diverse agroclimatic conditions ranging from north-eastern/north-western hills to down south under irrigated/rainfed, timely/late-sown, saline soils and mixed cropping. Indian mustard is cultivated in the area of 6.70 million ha with 7.96 million tones of production and 1188 kg/ha productivity respectively (AICRPRM, 2014).

Grain yield is a complex quantitative character and is vital influenced by environmental fluctuations. It fluctuates due to sensitivity of genotype to different environments. A Specific genotype does not always exhibit the same phenotypic characteristics under all the environments and different genotypes respond differently to a specific environment. A genotype is considered to be adaptive or stable if it has a high mean yield but a low degree of fluctuation in yielding ability where grown under diverse environments (Bicer and Sakar, 2006). Among the *rabi* crops Indian mustard is grown as a source of an important edible oilseed crop in India. In Gujarat condition, winter is very short and sometimes the temperature rise early in winter. Therefore, the identification of short duration and stable genotypes of Indian mustard that perform better over a wide range of environments with high yielded is required. Keeping this view, present investigation was carried out to identify the genotypes stable for desirable maximum number of traits across the wide range of environmental conditions.

MATERIALS AND METHODS

Fourteen genetically diverse and promising Indian mustard genotypes *viz.*, SKM 1403, SKM 1404, SKM 1413, SKM 1414, SKM 1423, SKM 1424, SKM 1428, SKM 1305, SKM 1331 and SKM 1219 including four check *i.e.*, NRCHB 506, Kranti (National checks) and GM 3, GDM 4 (State checks) were used for study.

[1, 2 & 3] Assistant Research Scientist, [4] Research Scientist

The experiment was conducted in Randomized Complete Block Design with four replications at five variable locations of Gujarat condition *i.e.*, Sardarkrushinagar, Junagadh, Amreli, Vijapur and Derol in *rabi* 2015-16. Each genotype was accommodated in a plot of eight rows of five meter length, with 45 cm x 10 cm. The recommended packages of practices were followed to raise the good crop. Observations were recorded on eight quantitative traits *viz.*, days to flowering, days to maturity, plant height (cm), length of silique (cm), seed per silique, number of silique per plant, test weight (g) and seed yield per plot (4.6 x 1.8 sq. mt) (kg). The data on days to flowering and maturity were recorded on plot basis. The data were subjected to analysis of variance as per the procedure suggested by Panse and Sukhatme (1978) for Randomized Complete Block Design. Genotype x environment interaction were found to be significant in respect of all the characters studied, hence the data were subjected to stability analysis model proposed by Eberhart and Russell (1966).

RESULTS AND DISCUSSION

Analysis of variance on eight characters for individual as well as pooled over the environment was carried out for each environment. The pooled analysis of variances revealed significant differences among the genotypes for all the characters except days to maturity, seed per silliquae and seed yield per plot (Table 1). This indicated that genotypes interacted strongly with the environments. Significant differences were observed among the environments indicated significant effect of environment was there in the expression of the traits. Similar results has been reported by Dhillon *et al.* (1999) and Brar *et al.* (2007). Environment (linear) component was significant for all the traits, while the linear component of environment interaction was significant for length of silique and number of silique per plant. The variance due to pooled deviation (non-linear) was highly significant for all the traits except number of silique per plant which reflect considerable genetic diversity in the material. These results are akin with the findings of Chattopadhyay *et al.* (2012) and Sah *et al.* (2015). A variety may be said to be stable over different environments if it shows unity or less than unity regression coefficient (bi) with lowest deviation (non-significant) from linear regression (S^2di). The mean, regression coefficient (bi) and deviation from regression (S^2di) for seed yield and yield contributing traits are presented in Table 2.

In the present investigation the magnitude of regression coefficient (bi) and deviation from regression varied from genotype to genotype. The first group consisting the genotypes which have high mean value, bi is equals to unity and S^2di is nearly zero were considered as stable genotype for all the environments studied. The genotypes SKM 1219 and SKM 1428 were stable for days to flowering as well as maturity. Genotypes *viz.*, SKM 1414, NRCHB 506, SKM 1404 and SKM 1219 were found stable for length of silique. For the trait seeds per silique the promising genotypes were Kranti, SKM 1413, GDM 4 and SKM 1219, while the genotypes GDM 4 and SKM 1428 were observed stable for test weight. The genotypes namely SKM 1424, SKM 1413 and SKM 1219 were found stable for seed yield per plot. Further the genotype SKM 1219 was observed to be desirable and stable for other yield contributing characters like days to flowering, days to maturity, length of siliquae and seeds per siliquae. In addition to that the genotype SKM 1305 was having high seed yield, $S^2di = 0$ and $b > 1$ indicating that this genotypes would perform better in favourable under environmental conditions.

The genotypes which are showing high mean value than over all mean but exhibiting above average stability with $bi > 1$ comes under the second group, indicated that they were highly sensitive to environment conditions. The genotypes performed well under favourable environmental conditions.

The third groups consisting the genotypes, which are showing high mean value than the population mean and exhibiting below average stability with $bi < 1$, indicating that these genotypes were least sensitive to environmental conditions. It revealed that the genotypes specifically adapted to poor environmental conditions. These findings were in agreement with the results of Dhillon *et al.* (1999), Brar *et al.* (2007), Yadava *et al.* (2010), Chauhan *et al.* (2010) and Sah *et al.* (2015).

CONCLUSION

Overall, it can be concluded that the genotypes *viz.*, SKM 1219, SKM 1413 and SKM 1424 were exhibited higher mean and stable performance over the environments for most of the yield components as well as for seed yield per plot. Thus, these genotypes can be utilized in future breeding programme for development of stable strains having wider adaptability.

Table 1 Analysis of variance for stability parameters for different characters in Indian mustard

Source of variation	d.f.	Days to flowering	Days to maturity	Plant height (cm)	Length of siliquae (cm)	Seeds / siliquae	Test wt (g)	No. of siliquae/Pl.	Seed yield / plot
Rep within Env.	10	5.375*	3.744	103.754	0.013	0.165	0.014	4249.125*	0.013
Varieties	13	5.981*	1.903	184.300*	0.156**	0.523	0.398**	3795.067*	0.022
Env. +(Var.* Env.)	56	73.496**	45.535**	163.111**	0.499**	1.308**	2.069**	15283.120**	0.125**
Environments	4	996.814**	605.448**	1073.108**	6.204**	11.833**	27.853**	181052.100**	1.327**
Var.* Env.	52	2.472	2.465	93.112	0.060*	0.498	0.086	2531.663	0.033
Environments (Lin.)	1	3987.254**	2421.794**	4292.434**	24.815**	47.333**	111.410**	724208.400**	5.307**
Var.* Env. (Lin.)	13	1.821	2.911	139.704	0.127**	0.233	0.107	4175.632*	0.033
Pooled Deviation	42	2.497**	2.151**	72.039**	0.035**	0.544**	0.073**	1841.983	0.030**
Pooled Error	130	0.6	0.556	18.11	0.01	0.115	0.011	1802.636	0.014
Total	69	60.776	37.314	167.103	0.434	1.16	1.754	13118.71	0.106

*, ** Significant at 5 % and 1 % levels, respectively.

Table 2 Mean and stability parameters for yield and its components in Indian mustard

Genotype	Days to flowering			Days to maturity			Plant height (cm)			Length of siliquae (cm)		
	Mean	bi	σ^2di	Mean	bi	σ^2di	Mean	bi	σ^2di	Mean	bi	di
SKM 1403	50	0.95	0.52	114.467	1.04	-0.54	182.193	1.45	20.97	4.453	0.97	0.02*
SKM 1404	49.733	1.07	0.97	114.267	1.07	1.36*	179.62	1.04	15.12	4.513	0.85	0.00
SKM 1413	50	1.03	2.03*	114.733	0.81	0.76	181.033	0.2	85.53**	4.633	0.8	0.02*
SKM 1414	49.067	0.98	3.06**	114.4	1.00	1.93*	164.74	0.15	126.43**	4.52	0.98	0.00
SKM 1423	48	1.01	-0.71	114.2	1.02	0.01	180.573	0.64	-10.08	4.713	1.21	0.01
SKM 1424	48.8	0.94	4.01**	113.8	1.00	5.06**	183.493	2.11	46.3*	4.44	0.9	0.03*
SKM 1428	50.733	0.95	-0.1	115.267	1.03	-0.5	183.753	1.81	65.9*	4.267	0.39*	0.04**
SKM 1305	50.267	1.02	2.63*	115.133	0.91	1.96*	181.373	0.86	22.13	4.107	1.03	0.07**
SKM 1331	50.533	0.86	2.1*	114.867	1.07	1.81*	183.353	1.68	86.86*	4.62	1.35*	-0.01
SKM 1219	52.533	1.09	-0.17	116.067	1.11	0.58	175.633	0.24	179.42**	4.167	0.93	0.04
NRCHB 506 (C_1)	49.6	1.04	4.09**	114.4	0.76	2.3**	189.14	0.44*	-16.15	4.52	0.89	0.01
KRANTI (C_2)	48.867	0.91	0.27	113.933	0.92	2.97**	188.313	1.85*	-12.58	4.607	0.95	0.05**
GM-3 (C_3)	50.667	1.18	2.98**	114.6	1.29*	0.27	187.78	1.04	-19.95	4.54	1.41	0.05**
GDM-4 (C_4)	50.2	0.96	0.09	113.867	0.98	1.16	183.16	0.49	79.48**	4.44	1.35*	0.00
Population Mean		49.929			114.571			181.726			4.467	

bi *, ** = Regression coefficient significantly different from unity at P = 0.05 and P = 0.01, respectively.
σ^2di *, ** = Deviation from regression significantly different from zero at P = 0.05 and P = 0.01, respectively.

Table 2 cont.

Genotype	Seeds per siliquae			Test weight (g)			Number of siliquae per plant			Seed yield per plot		
	Mean	bi	σ^2di	Mean	bi	σ^2di	Mean	bi	σ^2di	Mean	bi	σ^2di
SKM 1403	12.80	0.96	0.05	4.325	0.99	0.07**	365.867	0.84	-1147.37	1.770	0.84	0.02*
SKM 1404	13.387	0.71	0.01	4.547	1.05	0.09**	352.200	1.11	2723.43	1.650	1.21	0.03*
SKM 1413	13.107	1.05	0.04	4.779	1.22*	0.02*	365.000	1.32	-1124.56	1.682	0.94	0.00
SKM 1414	12.86	1.06	0.19	4.195	0.92	0.08**	376.733	1.43	1661.44	1.717	1.79	0.03*
SKM 1423	13.46	0.50	1.11**	4.108	0.86	0.22**	358.467	1.04	-102.32	1.695	1.03	0.05**
SKM 1424	12.367	1.33	1.57**	4.46	1.08	0.04**	399.133	1.22	339.89	1.856	0.96	-0.01
SKM 1428	12.553	1.49	0.03	4.075	0.95	-0.01	318.867	0.67*	-1877.89	1.623	0.42	0.03*
SKM 1305	12.693	1.14	0.28*	4.381	1.13	0.01	372.533	1.04	-953.48	1.699	1.18	0.01
SKM 1331	13.02	0.85	1.50*	4.144	1.13	0.15**	318.800	0.31*	-858.48	1.601	1.02	0.05**
SKM 1219	12.753	0.95	-0.01	3.973	0.99	0.06**	337.200	0.78	-913.74	1.679	1.02	0.02
NRCHB 506 (C_1)	13.053	1.33	0.69**	4.10	0.96	-0.01	360.933	0.96	-835.65	1.716	0.77	0.02
KRANTI (C_2)	13.42	0.78	-0.03	3.601	0.78	0.09**	409.800	1.04	3734.46*	1.736	0.97	0.00
GM-3 (C_3)	12.92	0.94	0.54**	4.125	1.01	0.05**	338.933	1.03	-1040.11	1.684	1.01	-0.01
GDM-4 (C_4)	13.073	0.92	0.00	4.089	0.93	0.00	391.467	1.2	-1501.28	1.787	0.85	-0.01
Population Mean		12.962			4.207			361.852			1.707	

bi *, ** = Regression coefficient significantly different from unity at P = 0.05 and P = 0.01, respectively.
σ^2di *, ** = Deviation from regression significantly different from zero at P = 0.05 and P = 0.01, respectively.

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Management of sucking insect pests infesting clusterbean, *Cyamopsis tetragonoloba* (Linnaeus) Taubert

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ABSTRACT

The investigation was carried out at Centre of Excellence for Research on Pulses, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during *kharif* 2011. Among the eleven treatments, imidacloprid 17.8 SL @ 0.005 per cent and acetamiprid 20 SP @ 0.004 per cent were found most effective against *Empoasca kerri*, while acetamiprid 20 SP @ 0.004 per cent and thiamethoxam 25 WG @ 0.0084 per cent showed higher efficacy against *Acaudaleyrodes rachipora*. The highest grain yield (679.33 kg/ha) and per cent increase in yield over control (159.16%) was recorded in the plots treated with acetamiprid 20 SP @ 0.004 per cent leading to highest economic return(1:97.58).

Key words : Bio-efficacy, insecticides, *Empoasca kerri*, *Acaudaleyrodes rachipora*, clusterbean, yield

Clusterbean, *Cyamopsis tetragonoloba* (Linnaeus) Taubert is an important seed as well as vegetable crop also called as *guar* represents its derivation from sanskrit word '*Gauaahar*' which means cow fodder or fodder of the livestock. In India, it is estimated to be cultivated in 42.55 lakh hectare with production and productivity of 24.14 lakh tonnes and 567 kg/ha, respectively. India accounts for 80 per cent of the total *guar* production in the world. In Gujarat, it is cultivated in 2.98 lakh hectare with a production of 1.79 lakh metric tonnes and productivity of 600 kg/ha (Anonymus, 2009). There are many factors responsible for low productivity of which infestation by insect pests is major one. Whitefly, *Acaudaleyrodes rachipora* Singh; leafhopper, *Empoasca kerri* Pruthiand thrips, *Megaleurothrips usitatus* Karnyare major sucking pests which cause damage to the clusterbean under north Gujarat condition (Pawar, 2012). The information on management of sucking pests of clusterbean is scanty in North Gujarat Agro Climatic Zone. Hence, the present investigation was carried out to find out the efficacy of different insecticides against major sucking pests of clusterbean.

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MATERIALS AND METHODS

The investigation on bio-efficacy of insecticides against sucking pests infesting clusterbean was carried out under North Gujarat conditions at Centre of Excellence for Research on Pulses, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during *kharif* 2011. Eleven insecticides (Imidacloprid 17.8 SL @ 0.005%, Thiamethoxam 25 WG @ 0.0084%, Acephate 75 SP@ 0.075%, Acetamiprid 20 SP @ 0.004%, Dimethoate 30 EC @0.03%, Triazophos 40 EC @ 0.05%, Clothianidin 50 WDG @ 0.025%, Diafenthiuron 50 EC @ 0.02%, Neem oil @ 0.5%, NSKE @ 5%, *Verticillium lecanii* @2.5 g/L) were tested against sucking insect pests of clusterbean (cv.GG-1) using Randomized Block Design (RBD) with three replications, gross plot size 4.00 x 2.25 m, net plot size 3.40 x 1.35 m and spacing of 45 x 15 cm.

Five plants from each net plot were selected randomly and tagged in each plot to record the population of sucking pests before spray as well as 1, 3, 7 and 10 days after spraying of insecticides. Number of *E. kerri* (nymphs and adult) and *A. rachipora*(adult and pupa) were counted separately from three leaves one each from top, middle and bottom region per plant at weekly interval during morning hours starting from two weeks after sowing till maturity of crop.

The grain yield obtained per plot was converted into kilogram per hectare and subjected to statistical analysis.On the basis of clusterbean yield harvested from the various treatments under study, the increase in yield over control as well as avoidable losses due to insect pests were calculated by following formula (Khosla, 1977).

$$\text{Avoidable loss (\%)} = \frac{\text{Highest yield in treated plot} - \text{Yield in treatment}}{\text{Highest yield in treated plot}} \times 100$$

$$\text{Increase in yield over control (\%)} = \frac{\text{Yield in treatment} - \text{Yield in control}}{\text{Yield in control}} \times 100$$

Efforts were also made to work out protection cost benefit ratio (PCBR) from the experimental data to assess economics of the different insecticidal treatments.

RESULTS AND DISCUSSION

The results pertaining to population of *E. kerri* and *A. rachipora*in different treatments recorded at different periods showed that all the treatments were found significantly superior over control in reducing the insect population.

Efficacy of insecticides against E. kerri

The data presented in Table 1 clearly indicated that significantly lowest *E. kerri* population was recorded in the plots treated with imidacloprid 17.8 SL @ 0.005 per cent (1.50/leaf)and was at par with acetamiprid 20 SP @ 0.004 per cent (1.64/leaf) after 1 day of spraying. Plots treated with diafenthiuron 50 EC @ 0.02 per cent, clothianidin 50 WDG @ 0.025 per centand thiamethoxam 25 WG @ 0.0084 per centregistered 2.15 to 2.43 hoppers per leaf and were equally effective against *E. kerri*. Further, acephate 75 SP @ 0.075 per cent (3.06) and triazophos 40 EC @ 0.05 per cent (3.21) were found moderately effective inreducing the *E. kerri*population on clusterbean. Among the treatments evaluated, *V. lecanii* @ 2.5g/ lit.andneem oil @ 0.5 per cent showed higher population of *E. kerri* (3.45).

Third day after spray (Table 1), again imidacloprid 17.8 SL @ 0.005 per cent registered the lowest (0.48)*E. kerri* population and it was at par with clothianidin 50 WDG @ 0.025 per cent (0.69) and acetamiprid 20 SP @ 0.004 per cent (0.75). In rest of treatments *viz.*,thiamethoxam 25 WG @ 0.0084 per cent, acephate 75 SP @ 0.075 per cent,neem oil @ 0.5 per cent, NSKE @ 5 per cent and *V. lecanii*@ 2.5 g/ lit the leafhopper population was noted with a range of 2.15 to 2.72 per leaf. The treatment of dimethoate 30 EC @ 0.03 per cent(2.78) was found least effective with higher population of *E. kerri*.

The same trend was followed after 7 days of spraying (Table 1).Imidacloprid17.8 SL @ 0.005 per cent was most effective treatment with minimum (0.12), while dimethoate 30 EC @ 0.03 per cent was least effective with maximum (2.81) *E. kerri* population in clusterbean. Acetamiprid 20 SP @ 0.004 per cent (0.30) and clothianidin 50 WDG @ 0.025 per cent (0.37) were equally effective with imidacloprid, whereas diafenthiuron 50 EC @ 0.02 per cent (0.60)was found to be moderately effective against *E. kerri*.

After 10 days of spray (Table 1),plots treated with imidacloprid 17.8 SL @ 0.005 per cent exhibited lowest (0.05)population of *E. kerri* which was at par with acetamiprid 20 SP @ 0.004 per cent (0.25), diafenthiuron 500 EC @ 0.2 per cent (0.30) and clothianidin 50 WDG @ 0.025 per cent (0.33). Treatment with thiamethoxam 25 WG @ 0.0084 per cent (1.78) and acephate 75 SP @ 0.075 per cent (1.96) found to be moderate in effectiveness against *E. kerri*. Among the treatments evaluated, *V. lecanii* @ 2.5 g/lit. (2.46) and dimethoate 30 EC @ 0.03 per cent (2.60) showed higher leaf hopper population, hence found least effective against the pest.

Efficacy of insecticides against A.rachipora

The data on efficacy of various treatments after 1 day of spraying (Table 2) clearly revealed that lowest population of *A. rachipora*(1.17/leaf) was found in plots treated with acetamiprid 20 SP @ 0.004 per centand it was at par with clothianidin 50 WDG @ 0.025 per cent(1.35) and thiamethoxam 25 WG @ 0.0084 per cent (1.58). Higher population of whitefly (3.79) was recorded in the plots treated with *V. lecanii*@ 2.5 g/lit andit was at par with dimethoate 30 EC @ 0.03 per cent, NSKE @ 5 per cent and neem oil @ 0.5 per cent with *A. rachipora* population ranged from 3.00 to 3.45 per leaf.

After 3 days of spraying(Table 2), acetamiprid 20 SP @ 0.004 per cent (0.71)once againshowed higher effectiveness against *A.rachipora* and it was at par with thiamethoxam 25 WG @ 0.0084 per cent (0.80) and clothianidin 50 WDG @ 0.025 per cent (1.22). The treatments *viz.*, diafenthiuron 50 EC @ 0.02 per cent, acephate 75 SP @ 0.075 per cent, imidacloprid17.8 SL @ 0.005 per cent and triazophos

Table 1 Efficacy of insecticides against *E. kerri* infesting clusterbean during *kharif*, 2011

Insecticides	Concentration (%)	No. of leaf hopper /leaf (day after spray)				
		Before spray	1	3	7	10
Imidacloprid 17.8 SL	0.005	2.30 (4.64)	1.41 (1.50)	0.98 (0.48)	0.78 (0.12)	0.74 (0.05)
Thiamethoxam 25 WG	0.0084	2.29 (4.74)	1.71 (2.43)	1.62 (2.15)	1.50 (1.76)	1.50 (1.78)
Acephate 75 SP	0.075	2.34 (4.98)	1.88 (3.06)	1.72 (2.47)	1.60 (2.09)	1.57 (1.96)
Acetamiprid 20 SP	0.004	2.24 (4.52)	1.46 (1.64)	1.11 (0.75)	0.89 (0.29)	0.86 (0.25)
Dimethoate 30 EC	0.03	2.27 (4.65)	1.94 (3.27)	1.81 (2.78)	1.82 (2.81)	1.76 (2.60)
Triazophos 40 EC	0.05	2.33 (4.93)	1.92 (3.21)	1.79 (2.72)	1.67 (2.29)	1.62 (2.12)
Clothianidin 50 WDG	0.025	2.33 (4.93)	1.63 (2.18)	1.08 (0.69)	0.93 (0.37)	0.91 (0.33)
Diafenthiuron 50 EC	0.02	2.32 (4.88)	1.62 (2.15)	1.25 (1.08)	1.04 (0.60)	0.89 (0.30)
Neem oil	0.5	2.85 (4.74)	1.98 (3.45)	1.72 (2.47)	1.67 (2.29)	1.66 (2.28)
NSKE	5	2.35 (5.02)	1.94 (3.27)	1.75 (2.56)	1.63 (2.16)	1.61 (2.11)
Verticillium lecanii	2.5 g/lit.	2.35 (5.02)	1.98 (3.45)	1.79 (2.72)	1.68 (2.34)	1.72 (2.46)
Control	-	2.26 (4.84)	2.38 (5.16)	2.32 (4.88)	2.35 (5.02)	2.37 (5.13)
S. Em. ±		0.05	0.06	0.07	0.08	0.07
C. D. at 5 %		NS	0.17	0.21	0.24	0.20
C. V. %		5.79	5.75	8.01	9.64	8.42

Figures in parentheses are retransformed values, those outside are $\sqrt{X + 0.5}$ values.

40 EC @ 0.05 per cent recorded whitefly population ranged from 1.64 to 2.34 per leaf and were equally effective against *A.rachipora*.However,higher population of *A.rachipora* was recorded in the treatment of *V. lecanii*@ 2.5g/lit. (3.45) followed by dimethoate 30 EC @ 0.03 per cent(2.82).

After 7 days of spraying, acetamiprid20 SP @ 0.004 per cent (0.41) was most effective (Table 2) against *A. rachipora*. However, thiamethoxam 25 WG @ 0.0084 per cent (0.53)and clothianidin 50 WDG @ 0.025 per cent (0.81) were also equally effective with acetamiprid. Spray of diafenthiuron50 EC @ 0.2 per cent, acephate 75 SP @ 0.075 per centand imidacloprid 17.8 SL @ 0.005 per cent in clusterbean proved moderately effective and registered 1.33 to 1.93 whiteflies per leaf. Higher (2.91) population of *A.rachipora*was noted in the plots treated with dimethoate 30 EC @ 0.03 per cent andit was at par with *V. lecanii*@2.5g/lit.,neem oil @ 0.5 per cent, NSKE @ 5 per centand triazophos 40 EC @ 0.05 per cent which showed the whitefly population in the range of 2.13 to 2.78 per leaf.

The results obtained after 10 days of spraying were almost similar to the results obtained during seven days after spraying(Table 2).Acetamiprid20 SP @ 0.004 per cent (0.19), thiamethoxam25 WG @ 0.0084 per cent (0.32) and clothianidin 50 WDG @0.025 per cent (0.53) treated plots exhibited significantly lower

Table 2 Efficacy of insecticides against *A. rachipora* infesting clusterbean during *kharif*, 2011

Insecticides	Concentration (%)	No. of whitefly/leaf (day after spray)				
		Before spray	1	3	7	10
Imidacloprid 17.8 SL	0.005	2.45 (5.50)	1.68 (2.32)	1.64 (2.19)	1.56 (1.93)	1.44 (1.58)
Thiamethoxam 25 WG	0.0084	2.43 (5.40)	1.44 (1.58)	1.14 (0.80)	1.01 (0.53)	0.90 (0.32)
Acephate 75 SP	0.075	2.42 (5.36)	1.69 (2.38)	1.58 (2.01)	1.44 (1.58)	1.34 (1.30)
Acetamiprid 20 SP	0.004	2.45 (5.52)	1.29 (1.17)	1.10 (0.71)	0.95 (0.41)	0.83 (0.19)
Dimethoate 30 EC	0.03	2.45 (5.50)	1.87 (3.00)	1.82 (2.82)	1.84 (2.91)	1.81 (2.78)
Triazophos 40 EC	0.05	2.46 (5.55)	1.74 (2.55)	1.68 (2.34)	1.62 (2.13)	1.58 (2.02)
Clothianidin 50 WDG	0.025	2.45 (5.51)	1.36 (1.35)	1.31 (1.22)	1.14 (0.81)	1.01 (0.53)
Diafenthiuron 50 EC	0.02	2.43 (5.45)	1.66 (2.27)	1.46 (1.64)	1.35 (1.33)	1.3 (1.25)
Neem oil	0.5	2.41 (5.31)	1.99 (3.45)	1.81 (2.76)	1.70 (2.40)	1.66 (2.28)
NSKE	5	2.43 (5.40)	1.93 (3.24)	1.80 (2.73)	1.69 (2.38)	1.59 (2.05)
Verticillium lecanii	2.5 g/lit.	2.47 (5.65)	2.07 (3.79)	1.99 (3.45)	1.81 (2.78)	1.71 (2.44)
Control	-	2.49 (5.70)	2.51 (5.81)	2.48 (5.65)	2.44 (5.47)	2.49 (5.73)
S. Em. ±		0.06	0.07	0.08	0.07	0.06
C. D. at 5 %		NS	0.20	0.24	0.22	0.19
C. V. %		6.40	6.81	8.73	8.66	7.70

Figures in parentheses are retransformed values, those outside are $\sqrt{X + 0.5}$ values.

population of the *A.rachipora*and were on par to each other. The highest (2.78)population of the *A.rachipora*was observed in dimethoate 30 EC @ 0.03 per cent treatment which was at par with *V. lecanii*@ 2.5g/lit. (2.44) and neem oil @ 0.5 per cent (2.28).

Imidacloprid 17.8 SL @ 0.005 per cent recorded minimum leaf hopper population and proved to be most effective treatment against leafhopper. Acetamiprid 20 SP @ 0.004 per cent, clothianidin 50 WDG @ 0.025 per cent and diafenthiuron 50 EC @ 0.02 per cent were found next best alternatives against *E. kerri.* In case of *A.rachipora*, acetamiprid 20 SP @ 0.004 per centand thiamethoxam 25 WG @ 0.0084 per cent and clothianidin 50 WDG @ 0.025 per cent were found effective. Early reports of Patel (2006) support the present findings who recordedimidacloprid @ 0.005 per cent as the most effective insecticide in reducing the population of leafhopper in cowpea. Similarly, Jyothirmai *et al.*(2002) also observed that the application of imidacloprid 200 SL @ 0.01 per cent as foliar spray drastically reduced the *E. kerri* infestation on groundnut. Earlier, the efficacy of acetamiprid 20 SP was studied by Patil *et al.* (2001), Baskaran *et al.* (2003) and Singh and Kumar (2005) against

Table 3 Effect of insecticides on grain yield, avoidable losses due to sucking pests and PCBR in clusterbean during *kharif*, 2011

Insecticide	Concentration (%)	Grain yield (kg/ha)	Increased in yield over control (%)	Avoidable loss (%)	PCBR
Imidacloprid 17.8 SL	0.005	545.00	108.01	19.77	1 :70.95
Thiamethoxam 25 WG	0.0084	569.33	117.17	16.19	1 :52.71
Acephate 75 SP	0.075	551.67	110.30	18.79	1 :66.89
Acetamiprid 20 SP	0.004	679.33	159.16	0.00	1 :97.58
Dimethoate 30 EC	0.03	292.33	11.57	56.96	1 :9.34
Triazophos 40 EC	0.05	390.00	48.85	42.59	1 :28.43
Clothianidin 50 WDG	0.025	630.00	140.45	7.26	1 :14.82
Diafenthiuron 50 EC	0.02	621.00	137.02	8.58	1 :48.86
Neem oil	0.5	398.00	51.90	41.41	1 :8.93
NSKE	5	387.00	47.70	43.03	1 :11.58
Verticillium lecanii	2.5 g/lit	392.00	34.35	48.18	1 :18.93
Control	-	262.00	-	61.43	-
S. Em. ±		9.38	-	-	-
C. D. at 5%		27.51	-	-	-
C. V. %		3.43	-	-	-

sucking pests of cotton. They recorded the acetamiprid 20 SP as the most promising insecticide in reducing the sucking pest incidence. These results corroborate the results of present investigation. The results are also are also in agreement with that of Patil *et al.* (2007) who mentioned that two sprays of clothianidin 50 WDG @ 20 and 25 g a.i./ha rendered very good protection to cotton crop against the leafhopper and whitefly in early season.

Impact on grain yield

The data (Table 3) on clusterbean grain yield revealed that the highest (679.33 kg/ha) grain yield was recorded in the treatment of acetamiprid 20 SP @ 0.004 per cent and was followed by clothianidin 50 WDG @ 0.025 per cent (574.67), thiamethoxam 25 WG @ 0.0084 per cent (569.00), diafenthiuron 50 EC @ 0.02 per cent (557.67), acephate 75 SP @ 0.075 per cent (551.67) and imidacloprid 17.8 SL @ 0.005 per cent (545.00).

Avoidable loss in yield due to pests

The avoidable losses in clusterbean yield varied from 7.26 to 56.96 per cent in different treatments (Table 3). However, it was recorded lowest (7.26%) in the treatment of clothanidin 50 WDG @ 0.025 per cent followed by diafenthiuron 50 EC @ 0.02 per cent (8.58%).

Increase in yield over control

The highest (159.16%) increase in yield over control was observed in plot treated with acetamiprid 20 SP @ 0.004 per cent (Table 3) followed by clothanidin 50 WDG @ 0.025 per cent (119.33%), thiamethoxam 25 WG @ 0.0084 per cent (117.17%) and diafenthiuron 50 EC @ 0.02 per cent (112.85%), however, the lowest increase in yield over control was obtained in treatment of dimethoate 30 EC @ 0.03 per cent (11.57%).

Economics

The highest (1:97.58) return was obtained with the treatment of acetamiprid 20 SP @ 0.004 per cent followed by imidacloprid 17.8 SL @ 0.005 per cent (1:70.95), acephate 75 SP @ 0.075 (1: 66.89). Among the treatments, the least (1:9.34 and 1: 8.93) returns were obtained with the treatments of dimethoate 30 EC @ 0.03 per cent and neem oil @ 0.5 per cent, respectively (Table 3).

In nutshell, spraying of acetamiprid 20 SP @ 0.004 per cent in *kharif* clusterbean crop proved best in

terms of efficacy against sucking insect pests leading to higher grain yield, per cent increase over control as well as higher economic return.

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Effect of flow rate and flow pattern of hot water on Overall Heat Transfer Coefficient for Double Pipe Heat Exchanger

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ABSTRACT

Double pipe multi pass heat exchanger with necessary accessories was designed, developed and evaluated for heat transfer performance. The performance of the heat exchanger for heating of chilled water was evaluated in terms of rate of heat transfer, terminal temperature, effectiveness and U-values, by varying the flow rate of hot water from 5, 10, 15, 20 and 25 lpm keeping flow rate of medium to be heated in inner pipe at 1.0 lpm. The values of maximum temperature rise were in first pass of the HE at all flow rates of hot water in both flow patterns. The actual U values of the heat exchanger ranged from 390.08 to 483.92 W/m^2 K and 386.21 to 437.90 W/m^2 K using hot water from solar thermal system in counter current and co-current respectively. It was observed that actual U value increased as the flow rate of service fluid increased up to 20 lpm in both the flow patterns. The actual U values and effectiveness of the heat exchanger were found higher in case of counter current flow pattern than that of co-current flow pattern at all flow rates studied. The regression equations obtained correlating flow rate of hot water and actual U values were $y = 305.1x^{0.1437}$ (R^2=0.9146) and $y=338.6\ x^{0.0816}$ (R^2 = 0.9913) for counter and co-current flow pattern respectively.

Key word: Overall heat transfer coefficient, counter current, co-current, heat exchanger

Double pipe heat exchanger is commonly used for heating or cooling of liquid products in which hot and cold fluids flow through two concentric pipes in the same (co current) or in opposite (counter current) direction. It can be made from pair of single length of pipe or from a number of length arranged in a vertical row with section connected at alternate ends. Smaller diameter pipe is inserted within another pipe and welding of the outer jacket to the inner pipe is done or packed stuffing box is provided to permit different movement and the removal of inner pipe for cleaning or maintenance purpose. The design aspects of double pipe heat exchanger have been described (Arora and Domkundvar, 1990; Yadav, 1994). Double pipe section available commercially range from 5 to 10 cm pipe size outer pipe with inner pipe varying from 1.9 to 6.35 cm size. These are suitable for low flow rates and high temperature range. They can withstand high pressure because of small diameter pipes and this configuration is also very suitable, when one or both fluids are at high pressure (Mehrabian*et al.*, 2002). Space requirement is normally high as compared to Plate Heat Exchanger. However, it can be ceiling or wall mounted or bulk headed through a wall, thereby saving floor space. Uniform flow distribution and cleaning in place is done very easily. Double-pipe heat exchangers can be arranged in various series and parallel arrangements to meet pressure drop and mean temperature difference requirements. The major use of double-pipes exchangers is for sensible heating or cooling of process fluids where small heat transfer areas (to 50 m^2) are required (Devore, *et al.*, 1980).

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MATERIALS AND METHODS

The system mainly consists of double pipe 4-pass (each of 2.0 m long) heat exchanger fabricated from AISI 304 grade stainless steel, supply and collecting S.S. tanks, hot water circulating centrifugal pumps and necessary valves and flow metering devices. The hot water was circulated in annular space in a helical

movement to increase the heat transfer rate by inserting a helical coil on the inner pipe. The arrangement in the design of the heat exchanger (HE) is made in such a way that it is possible to supply hot water in co-current and counter current flow pattern. The microprocessor based data logger having RTD sensors was used to measure the temperature of cold and hot water at various points of the HE. The double pipe multi pass heat exchanger was fabricated as shown in Fig. 1. Argon gas welding was used for joining of pipes and pipe fittings and 140 grit finishing was carried out of all surfaces. All pipe fittings and valves were joined taking upmost care to prevent leakage of the fluids. The pass arrangement is made in such a way that the milk flows successively in each pass from supply tank to collection tank. The service fluid inlet and outlet were connected in each passat bottom and upper side of the pass respectively. Necessary valves were connected in service fluids pipes and milk pipes to adjust and control the flow rate. The temperature sensors of data logger were connected at all entry and exit points of milk and hot water in each pass. Rotameters were connected in inlet pipes of service fluid in all passes to measure the flow rates of service fluid. Separate pumps were used with necessary flow control valves in each pass for the supply of the service fluid in the respective pass. The technical specifications of the double pipe heat exchanger are given in Table 1.

Table 1 Technical specifications of double pipe heat exchanger

Part	Material	Inner Dia (mm)	Outer Dia (mm)	Thickness (mm)	Length for each pass (m)
Milk pipe(Inner) and service fluid supply pipe	SS304	21.0	25.0	2.0	2
Service fluid pipe(Outer)	SS304	59.3	62.5	1.6	2
Insulation	Glass wool	62.5	121.0	29.25	2
Cladding for Insulation	SS304	121.0	125.0	2.0	2
Milk tanks	SS304	400.0	404.0	2.0	0.5 m height
Helical coil	SS304	26.0	38.0	Coil rod dia.: 12.0 Pitch: 25.0	2
Service fluid connecting pipes	C-PVC	25.0	27.0	1.0	As per requirement

Operational parameters

To optimize the flow rate and flow pattern for maximum heat transfer, the heat exchanger was evaluated by varying rate of hot water flow as service fluid and chilled water as medium to be heated. The temperatures of chilled water to be supplied in the heat exchanger with Co-current(parallel) and Counter current flow pattern in all pass with 5,10,15,20 and 25 lpm flow ratesof service fluid(solar & PNG hot water) were evaluated.

Evaluation of heat transfer performance

In the present design of the double pipe multi-pass heat exchanger, heat transfer takes place from hot water as service fluid to chilled water. The rate of heat transfer in liquid to liquid heat transfer system under various

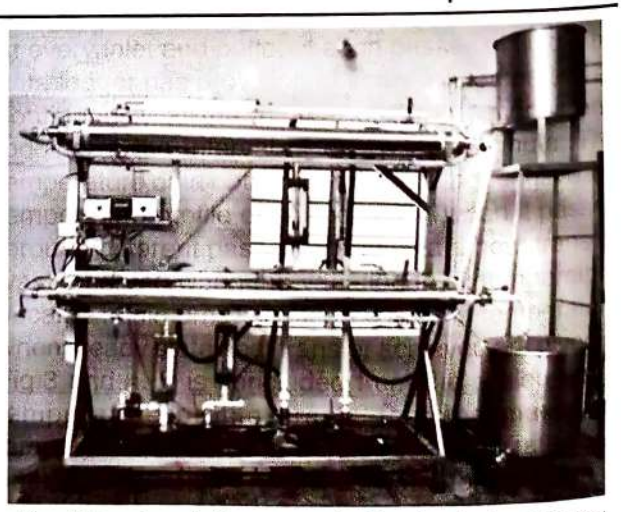

Fig. 1 Experimental four pass double pipe heat exchanger

operating conditions was calculated by using fundamental equations of heat transfer.

Heat transfer area

The heat transfer area in each pass is same and it is estimated by using the following equation.

$$A = \pi \times dm \times Lp \times Mo.\ of\ passes$$

Where, dm = Mean diameter of the milk pipe, m

Lp = Length of each pass, m

Mass flow rate

Volumetric flow rate of hot water measured by rotameter was converted in mass flow rate taking average density of 0.9748 g/cm^3 (974.8 kg.m^{-3}) in the temperature range of 70 to 85°C for theoretical U value calculation. For practical purposes, 1 lpm was taken as 1 kg/m for both milk and water.

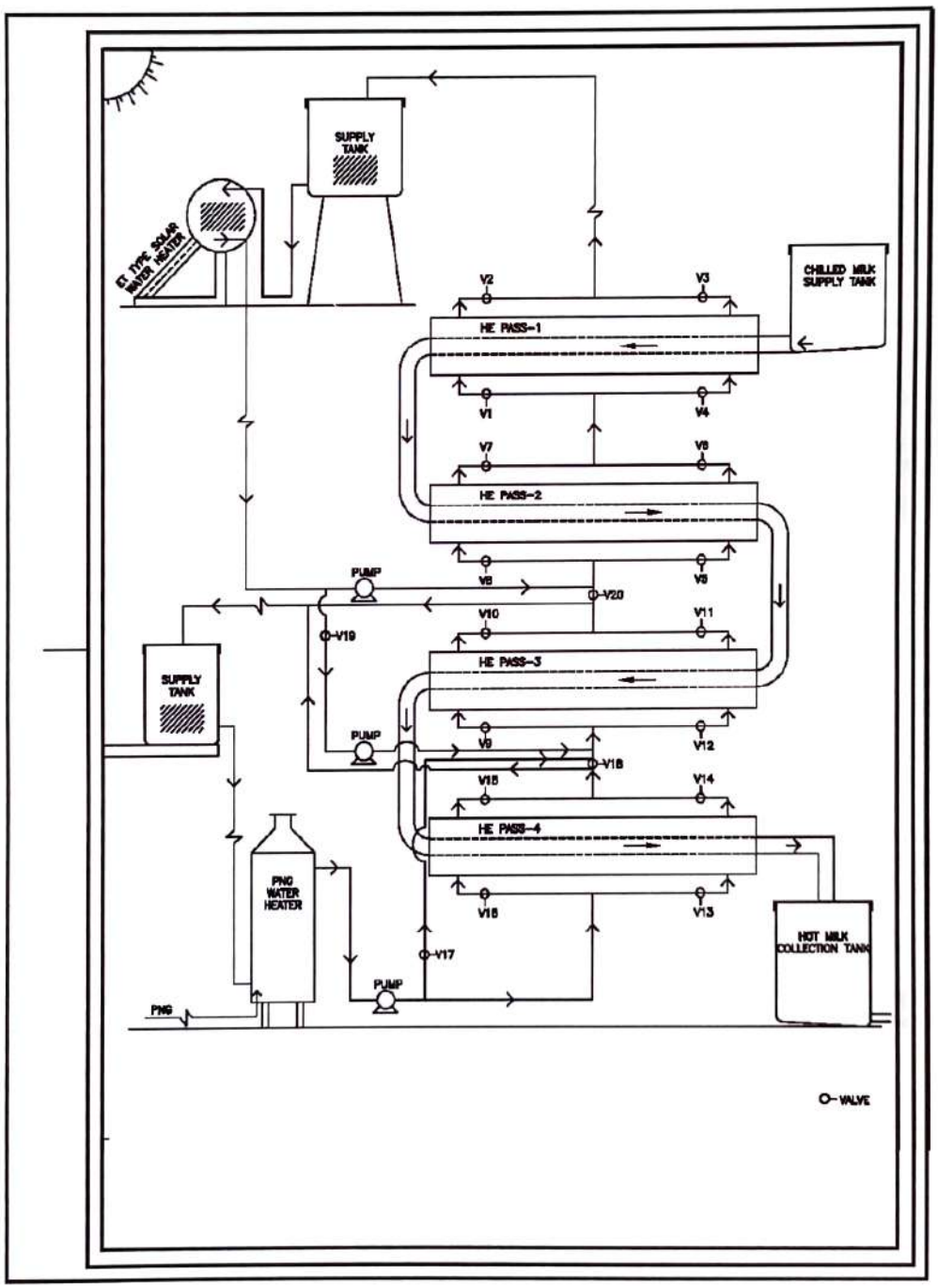

Fig.2 Schematic diagram of experimental heat exchanger

Logarithm mean temperature difference (LMTD)
Logarithm mean temperature difference (LMTD) concept in heat transfer is applied when the temperature difference between the hot and cold fluid is not constant throughout the whole length of the heat exchanger. In the present design of the heat exchanger, the temperature of heating medium drops while the temperature of medium to be heated increases. The LMTD was calculated by measuring inlet and outlet temperature of both the fluids in all the trials.

Co-current (parallel) flow arrangement
Each pass of the heat exchanger has two inlet and two outlet valves in the service fluid pipe. The co-current flow arrangement in each pass is done by keeping the entry and exit of milk and hot water at the same end of the heat exchanger i.e. both fluids move in the same direction. The direction of the milk flow or chilled water flow was in one direction in the order of first pass to last pass. Practically, in the heat exchanger, it is achieved by opening the even number valves and closing the odd number valves as designated in Fig.2(valve 1 to valve 16). LMTD for co-current (Parallel) flow pattern was calculated by using the following equation.

$$\Delta \emptyset m = \frac{\Delta Ti - \Delta To}{ln \frac{\Delta Ti}{\Delta To}}$$

Where,
$\Delta \emptyset m$ = LMTD, °C
ΔTi = Temperature difference between hot water and milk at inlet, °C
ΔTo = Temperature difference between hot water and milk at outlet, °C

Counter current flow arrangement
In the counter current flow, the milk enters in the heat exchanger, while the hot water exits. Thus, the milk and hot water (heating medium) flows in opposite direction. This type of flow was achieved by opening the odd number valves and closing the even number valves as designated in Fig.2 (valve 1 to valve 16).LMTD in counter flow arrangement was calculated using the following equation

$$\Delta \emptyset m = \frac{\Delta T1 - \Delta T2}{ln \frac{\Delta T1}{\Delta T2}}$$

Where,
$\Delta \emptyset m$ = LMTD, °C
$\Delta T1$ = Temperature difference between hot water inlet and milk outlet, °C
$\Delta T2$ = Temperature difference between hot water outlet and milk inlet, °C

Heat transfer rate
This is the amount of heat transferred for the given mass flow rate of milk to raise the temperature to a required level. The amount of heat required to raise the temperature was calculated using the following equation.

$$Q_m = M_m \times C_{pm} \times \Delta t$$

Where,
Q_m = Heat load, kJh^{-1}
M_m = Mass flow rate of chilled water in the heat exchanger, kgh^{-1}
C_{pm} = Specific heat of water, kJ/kg K
Δt = Difference between chilled water outlet and inlet temperature of respective pass, °C

Actual overall heat transfer coefficient
The values of overall heat transfer co-efficient (U-values) were calculated using the following equation.

$$Q_m = Ua \times A \times \Delta \theta m$$

Where,
Q_m = Heat gain by chilled water, $kJh^{-1} = Q_m/3.6$ W
Ua = Actual overall heat transfer coefficient, W/m^2 K
A = Heat transfer area, m^2
$\Delta \theta m$ = LMTD of respective flow pattern, °C

RESULTS AND DISCUSSION

Effect of hot water flow rate on temperature profile of chilled water
The temperature sensors of data logger were inserted at every inlet and outlet of each passes of fluid. The data logger has provision of scanning temperatures continuously at the interval of three seconds and logging at the interval of every three minute. The temperature data obtained from data logger gave the temperature profile of chilled water, when it passed through different passes. Steady state heat transfer was observed when the variation in all temperature became minimum. The mean values of temperature when steady state heat transfer achieved are given in Fig.3 and 4. It is concluded from the chilled water temperature profile graph, that the maximum temperature rise was in 1st pass in all flow rates and both flow patterns. The chilled water temperature at the end of first pass was observed in the range of

43.10°C to 54°C. Then the rise of temperature was decreased in successive passes. Higher temperature rise of chilled water in first pass is due to the higher temperature difference between hot water and chilled water.

Effect of hot water flow rate on actual U value

The effect of flow rate of hot water on actual U values (U_a) was calculated to obtain optimum value of hot water flow rate. The actual U values of heat exchanger for two passes in which hot water from solar thermal system was used and in remaining two passes where in PNG fired hot water was used at different flow rates of hot waterare shown in Fig. 5. This type of hot water circulation pattern was used in the month of January and February 2016 as the temperature of hot water from ETC was not adequate. The actual U values

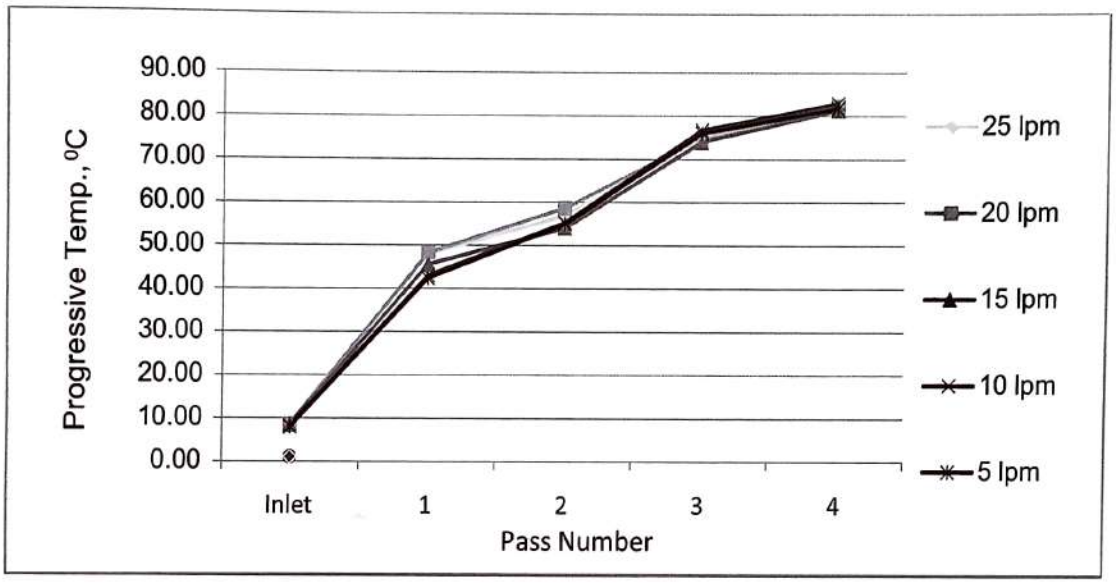

Fig. 3 Progressive terminal temperature of the chilled water (counter current)

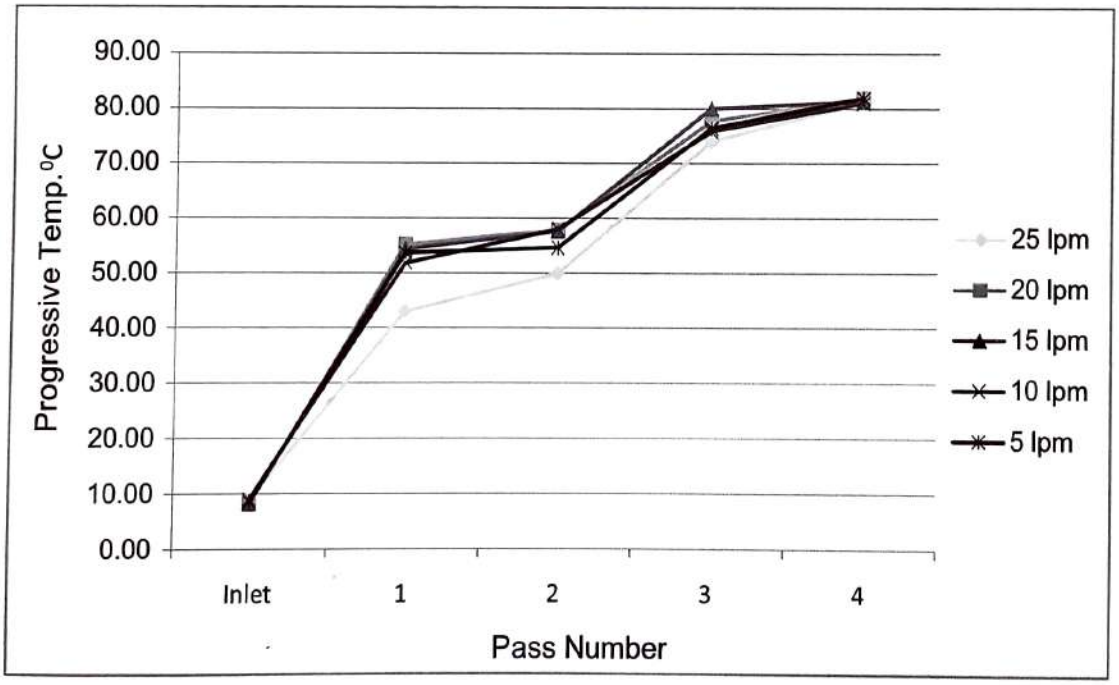

Fig. 4 Progressive terminal temperature of the chilled water(co current)

ranged from 390.08 to 483.92 W/m² K and 386.21 to 437.90 W/m² K for solar thermal heating in counter current and co current respectively. While, the actual U values ranged from 451.05 to 503.29 W/m² K and 429.36 to 479.10 W/m² K for PNG hot water heating in counter current and co current respectively. The relationship between flow rate of hot water and the actual U values for solar heating and PNG hot water heating revealed that actual U value increased as the flow rate increased up to around 20 lpm. This was in line with observation reported by Desai and Borse (2013).

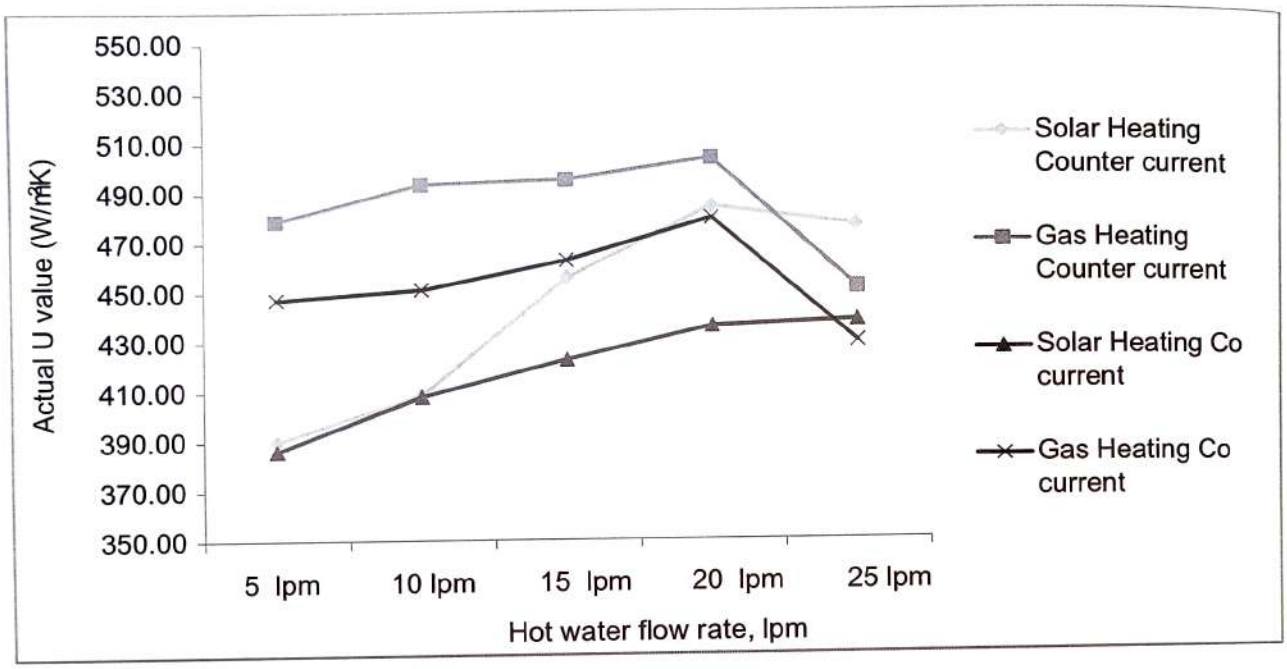

Fig.5 Relationship between hot water flow rate and actual U values for different flow pattern for chilled water heating

Effect of flow pattern on actual U values

The heat exchanger had provision of circulating the hot water in cocurrent and counter current pattern in each pass to evaluate the effect of flow pattern on actual U values. The effect of flow pattern on actual U values for different flow rate is graphically shown in Fig.5.The U values for solar heating as well as PNG hot water heating were found higher in case of counter current flow pattern than that of co current flow pattern at all flow rate studied. Similar observations were reported by Shirgire*et al.* (2014). Therefore, it is desirable to adopt counter current flow pattern to get higher U values of the heat exchanger which helps in reducing the area requirement of the heat exchanger.

CONCLUSION

At steady state heat transfer conditions, the values of maximum temperature rise were in first pass of the heat exchanger at all flow rates of hot water as well as in both flow patterns. The actual U values of the heat exchanger ranged from 390.08 to 483.92 W/m² K and 386.21 to 437.90 W/m² K for heating process using hot water from solar thermal system in counter current and co current respectively. While, the actual U values ranged from 451.05 to 503.29 W/m² K and 429.36 to 479.10 W/m² K for PNG fired hot water heating in counter current and co current respectively. It is noticed that actual U value increased as the flow rate of service fluid increased up to 20 lpm in both the flow patterns. The effect of flow rate of hot water on U values of heat exchanger was significant. Beyond 20 lpm flow rate of hot water, U-values of the heat exchanger decreased. The actual U values for solar heating as well as PNG hot water heating were found higher in case of counter current flow pattern than that of co current flow pattern at all flow rates studied. Therefore, it is desirable to adopt counter current flow pattern to get higher U values of the heat exchanger, which helps in reducing the area requirement of the heat exchanger. The equations obtained correlating flow rate of hot water and actual U values were

$y = 305.1x^{0.1437}$ (R^2=0.9146) and $y=338.6\ x^{0.0816}$(R^2 = 0.9913) for counter and co-current flow pattern respectively.

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Variability in selfed progenies of okra (*Abelmoschus esculentus* (L.) moench) through North Carolina Designs

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ABSTRACT

The selfed progenies developed through North Carolina Designs (NCD I, II and III) in F_2 populations of okra *viz.*, HRB-55 x Kamini (cross-1) and BO-13 x Parbhani Kranti (cross-2) were used to study the variability. The results of yield was observed higher in NCD III for both the crosses. The value of CV percent was higher in NCD II for yield in two cross. The results of plant height and intermodal length was higher in NCD III and CV percent higher in NCD I in cross 1. Intermodal length was higher in NCD III and CV percent higher in NCD I in cross 2. The test of significance between the means of selfed progenies developed through North Carolina designs I, II and III for yield per plant, plant height and number of nodes per plant was observed significant in both cross except plant height in cross 2 for NCD III. The mean value of middle inter-nodal length of plant was non significant in NCD I and II for the cross 1.

Key word : Variability, NCD I, NCDII, NCD III and okra

Okra (*Abelmoschus esculentus* L. Moench) is one of the chief and abundant vegetable grown extensively throughout the world in summer and rainy seasons. The genetic improvement of any crop relies mainly on the presence of substantial magnitude of variability in the population. Plant breeders are always engaged with various breeding procedures for crop improvement, out of which, till now, is to hybridize diverse genotypes possessing complementary desirable characters, followed by selection in F_2 and subsequent generations, combining these characteristics from both the parents. The mating design refers to a system of mating employed to develop progenies of certain kinds. Therefore, the present study on variability in okra through NC designs was planned to select proper design.

MATERIALS AND METHODS

The seeds of F_1 generation of two crosses of okra *viz.*, HRB-55 x Kamini (Cross 1) and BO-13 x Parbhani Kranti (Cross 2) were obtained from the Vegetable Research Station, Junagadh Agricultural University, Juanagdh and F_2 generation was obtained by selfing the F_1 generation at the same place during the *kharif* 2006. The plants of F_2 population of the crosses were utilized for generating the experimental materials for NCD I, II and III during the summer 2007.

North Carolina Design I, II and III

Crosses for NCD I (Comstock and Robinson, 1952) were made in F_2 populations of HRB-55 x Kamini (Cross 1) and BO-13 x Parbhani Kranti (Cross 2) using randomly selected plants each for male and female. The selected plants as male (five plants) and female (twenty five plants) were selfed by bagging the flower with white butter paper and the seeds were collected at the time of maturity. Thus, the experimental materials for each cross in this design consisted of 30 selfed progenies (F_3) for NCD I. From each F_2 base population (Cross 1 and Cross 2) five plants selected as males and females were selfed for each cross. Thus, the experimental material for each cross in this design consisted 10 selfed progenies (F_3) for NCD II. The experimental material for North Carolina Design III was generated using the parents of each base population i.e. HRB-55 and Kamini for Cross 1 and BO-13 and Parbhani Kranti for Cross 2 as females and five randomly selected plants as male from their respective F_2. The selected

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male and female plants were selfed. Thus, the experimental material obtained from each cross in this design 7 selfed progenies for NCD-III.

Experimental designs

The experimental selfed progenies developed in NCD I, II and III were evaluated in a compact family block design with two replications for designs I & II and three replications to maintain error degrees of freedom for design III. Each entry was sown in a single row having 20 plants, with a spacing of 60 x 30 cm. Thus, the plot size was 6.0 x 0.6 m. All the recommended agronomic practices were followed to raise the good crop. The observations were recorded for yield per plant (g), plant height (cm), number of nodes per plant and internodal length (cm) from 10 randomly selected plants from each progeny.

RESULTS AND DISCUSSION

Mean, range and coefficient of variation

The overall mean, range and coefficient of variation for four character of okra under study for North Carolina Designs I, II, III are given in Table 1.

Selfed progenies (F_3) of parents plants of NCD

The results of selfed progenies presented in Table 1 indicated that the highest overall yield of 133.62 gm/ plant was observed in NCD III followed by 117.14 gm/ plant in NCD II and 116.55 gm/plant in NCD I for the cross 1 (HRB-55 x Kamini). It was the highest (139.44 gm/plant) in NCD III followed by NCD I (129.32 gm/ plant) and NCD II (121.77 gm/plant) for the Cross 2 (BO-13 x Parbhani Kranti). The value of CV (16.41%) was higher for the cross 1 and it was 15.12% for the cross 2 in NCD II, when it was compared with NCD I and NCD III. Mean plant height was the highest (93.05 cm) in NCD III followed by 92.73 cm in NCD II and 92.64 cm in NCD I for the cross 1. In cross 2, it was the highest (100.32 cm) in NCD I followed by 97.83 cm in NCD II and 95.50 cm in NCD III. The higher variability was observed in NCD I for both the crosses. The average number of nodes per plant were observed higher in NCD II for both the crosses. The value of CV was higher in NCD I for the cross 1 and NCD II for the cross 2. The mean value of middle inter-nodal length of plant was the highest in NCD III followed by NCD II and NCD I for both the crosses and the variability was the highest in NCD I followed by NCD II and NCD III for both the crosses. Comparison of NCD with their selfed progenies (F_3s)

The mean values of various characters obtained in different North Carolina designs were compared with their respective selfed progenies of parent plants selected from F_2 (F_3s) grown adjacent to the plots of respective designs. The difference in mean values was tested by Student 't' test (Table 2). The results indicated that the fruit yield was significantly higher in all the NCD I, II and III, when it was compared with their F_3s in both the crosses). Comparison of biparental mating and selfing was made in a chickpea crosses by Singh (2004) and he reported that the mean values for all the traits except primary branches were higher in BIPs than F_3 progenies. The number of nodes per plant was found higher and significant in NCD I, II and III for both the crosses, when they were compared with selfed progenies. The mean plant height was significantly higher in all NCD I, II and III for the cross 1 and NCD I and II for the cross 2. It was non significant in NCD III for the cross 2. The mean value of middle inter-nodal length of plant was non significant in NCD I and II for the cross 1. However, it was significantly higher in NCD III (Cross 1) and in NCD I,II and III (cross 2), when it was compared with selfed progenies. Genetic variability created through biparental mating in chickpea was estimated by Kampli *et al.* (2002 in the F_2 of the cross ICCV-10 x BG 256 of chickpea. The biparental population (BIP) had better mean performance than the F_3 selfs for all the characters under study. The lower limit of the range was, in general, smaller for almost all the characters in the BIPs. The upper limit was also increased in the desired direction for all the characters. Sufficiently high genetic variation was maintained in the BIP population for most of the characters except for secondary branches. The BIPs also exhibited improved estimates of heritability and genetic advance. Ortiz and Golmirzaie (2002) studied hierarchical and factorial mating designs (also known as North Carolina mating designs I and II, respectively) to determine these variance components. The results of design I gave a negative digenic variance (σ^2_D), this design provided almost the same estimate of narrow-sense heritability (h^2) for tuber yield as that obtained in design II. Results suggest that two females per male may not be enough for design I in tetrasomic potato. Four females per male are preferable to determine σ^2_A in design I for this tetrasomic crop. Deor (2004) studied on biparental progenies in sprouting broccoli (*Brassica oleracea* var. *italica* Plenck). Biparental progenies were developed in F_2 generation of a heterotic cross *viz.*, PS x PK-1 by using North Carolina design 1. Besides the development of BIP's, F_2 population was bud pollinated to produce F_3 progenies which were evaluated in randomized block

Table 1 Mean, range and coefficient of variation for different characters of selfed progenies developed throughNorth Carolina Designs I, II and III.

Sr. No.	Character		Cross 1 (HRB-55 x Kamini)			Cross 2 (BO-13 x Parbhani Kranti)		
			North Carolina Designs			North Carolina Designs		
			I	II	III	I	II	III
1	Yield / plant (gm)	Mean	116.55	117.14	133.62	129.32	121.77	139.44
		Range	79.46-159.38	75.64-160.20	100.00-160.00	77.02-184.34	78.14-153.00	100.00-163.50
		CV %	12.78	16.41	9.26	12.07	15.12	9.47
2	Plant height (cm)	Mean	92.64	92.73	93.05	100.32	97.83	95.50
		Range	58.00-120.00	70.00-125.00	73.00-115.50	62.00-128.00	68.28-123.71	75.50-118.00
		CV %	13.28	9.72	10.08	13.33	11.23	9.46
3	No. of Nodes / plant	Mean	13.07	13.78	13.75	14.24	14.53	13.82
		Range	8-20	9-19	10-18	11-19	10-22	11-17
		CV %	14.68	12.33	9.32	10.86	12.12	8.30
4	Internodal length (cm)	Mean	5.38	5.54	6.12	5.84	5.85	6.61
		Range	2.36-11.55	3.45-8.60	4.08-9.64	2.67-9.80	3.59-8.96	4.97-8.89
		CV %	25.75	17.36	14.39	21.20	15.80	12.21

Table 2 Test of significance between the means of progenies developed through different North Carolina Designs and their selfed progenies (F_3) of parents.

Sr. No.	Character	Cross 1 (HRB-55 x Kamini)			Cross 2 (BO-13 x Parbhani Kranti)		
		North Carolina Designs			North Carolina Designs		
		I	II	III	I	II	III
1	Yield / plant (gm)	*	*	*	*	*	*
2	Plant height (cm)	*	*	*	*	*	NS
3	No. of Nodes / plant	*	*	*	*	*	*
4	Internodal length (cm)	NS	NS	*	*	*	*

* Significant at P = < 0.05 NS :Non Significant

design. The analysis of variance of BIP's and F_3 progenies revealed significant differences for all the traits. T-test also indicated significant differences in the mean performance of the biparental and F_3 progenies for all the traits except for plant frame. Ved and Varma (2006) made comparison of biparental progenies with selfed F_3 population in barley cross of RD 2035 x RD 2535 to assess the impact on generating variability for grain filling period, peduncle length, spikelets per spike, harvest index and grain yield per plant. They reported that BIPs had better mean performance than their F_3 progenies for all the characters. The lower limit of the range was, in general, smaller for almost all the characters in the BIPs while upper limit also increased in the desired direction for all the characters. BIPs were able to provide greater variability for selection of desirable plants for higher grain yield. Increased mean performance of BIPs population exhibited higher estimates of heritability and genetic advance for all the characters. Patel (2010) compared mean of different characters of NCD III with F_3 progenies, they were higher for yield, plant height, leaf length and leaf breadth in two cross of tobacco in NCD III than F_3 progenies.

CONCLUSION

The selfed progenies developed through North Carolina Designs (NCD I, II and III) in F_2 populations of okra were used to study the variability. The results of mean yield of okra higher in NCD III and CV percent in NCD II were observed in both the crosses. The value of CV percent was higher in NCD II for yield in two cross. The test of significance between the means of selfed progenies developed through North Carolina designs I, II and III for yield per plant, plant height and number of nodes per plant was observed significant in both cross except plant height in cross 2 for NCD III. The mean value of middle inter-nodal length of plant was non significant in NCD I and II for the cross 1.

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Influence of different spacing and plant growth regulators on flower yield and vase life of spider lily under Middle Gujarat Agro Climatic conditions

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ABSTRACT

An experiment was conducted during 2013-14 to 2015-16 to study the influence of different spacing and plant growth regulators on growth and flower yield of spider lily under middle Gujarat Agro Climatic conditions at College Nursery, Department of Horticulture, B. A. College of Agriculture, Anand Agricultural University, Anand. Local cultivar of spider lily was used in experiment and transplanting of spider lily crop is carried out in *Kharif* season of the year 2013 i.e. second fortnight of July, 2013. Three different planting distance *viz.* 90 x 45 cm. 60 x 60 cm and 60 x 45 cm and foliar spray of two different plant growth regulators *viz,* gibberellic acid and napthalic acetic acid were used as treatment. Spider lily crop grown at distance of 60 x 60 cm and two spray of Gibberellic acid @ 200 mg per litre was most effective treatment which improved the flower quality and increased the flower yield of spider lily.

Key words: Spider lily, growth regulators

Spider Lily (*Hymenocallis speciosa* L.) belongs to the genus Hymenocallis of Amaryllidaceae family. It comprising of about 40 species of bulbous plants and of native of Peru, South America. It is cultivated for the beneficial white fragrant flowers. *Hymenocallis speciosa* L. is commonly called 'spider Lily' whose flower have spider like appearance. Its white mild sweet fragrant flowers are utilized as different ornamentals preparation like *venies*, *gajras*, garlands etc. Lily flowers are mostly used in the preparation of garlands especially for colour contrast because of their white colour. Spider Lily is commercially grown and the area under cultivation is increasing day by day. In recent years, scientists have given due attention for improving the growth, flowering, yield and quality of flower crops with the application of plant growth regulators in various ways. Response of flowering plants to growth regulators treatments are being studied with a view of having compact plants with greater number of flowers and also to hasten or delay flowering according to the need of growers (Yawale *et al.*, 1998).

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MATERIALS AND METHODS

The research experiment was conducted on 'influence of different spacing and plant growth regulators on growth and flower yield of spider lily under middle Gujarat agro climatic conditions' at College Nursery, Department of Horticulture, B. A. College of Agriculture, Anand Agricultural University, Anand during the year 2013-14 to 2015-16. Local cultivar of spider lily was used in experiment and transplanting of spider lily crop is carried out in *Kharif* season of the year 2013 i.e. second fortnight of July, 2013. The experiment was carried out in Middle Gujarat Agro Climatic Zone-III. The recommended dose of fertilizer of 20 ton per hectare Farm Yard Manure (FYM) and 300:200:200 (NPK) kg/ha were given in the experiment. In which, nitrogen was applied in 4 equal splits in June, September, December and March months while, Farm Yard Manure (FYM), phosphorus and potash were applied as basal dose.

Three different planting distance and foliar spray of two different plant growth regulators *viz*, gibberellic acid and napthalic acetic acid were used as treatment and it was comprised four replications. The experiment was laid in Split Plot Design (SPD) and consist of three spacing treatments *viz*., S_1- 90 x 45 cm, S_2- 60 x 60 cm S_3- 60 x 45 cm in main plot and 8 Foliar spray treatments *viz*., T_1 - gibberellic acid @ 100 mg/l, T_2-Foliar spray of gibberellic acid @ 150 mg/l, T_3-Foliar spray of gibberellic acid @ 200 mg/l, T_4-Foliar spray of Napthalic acetic acid (NAA) @ 50 mg/l, T_5-Foliar spray of Napthalic acetic acid (NAA) @ 100 mg/l, T_6-Foliar spray of Napthalic acetic acid (NAA) @ 150 mg/l, T_7-Water Spray (control) and T_8-No spray (control) in sub plot. Spraying of plant growth regulators twice at 45 and 60 days after planting of bulb in first year. From second year onwards spraying will be done at 45 an 60 days after cutting of leaves. Cutting of leaves will be done in the month of March.

RESULTS AND DISCUSSION

Number of flower buds per stalk

The individual effect of spacing on number of flower buds per stalk was found significant during the years (Table 1). The significantly maximum number of flower bud per stalk was recorded with treatment of spacing of 60 x 60 cm in the year 2013-14 and 60 x 45 cm in the year 2014-15 and 2015-16 while, effect of spacing on number of flower buds per stalk was found non-significant in pooled analysis. Whereas, the individual effect of plant growth regulators on number of flower buds per stalk was found significant during the all the years and in pooled analysis. The significantly maximum number of flower buds per stalk was recorded with gibberellic acid @ 200 mg/l treatment as compared to other treatments of plant growth regulators during all the years and in pooled analysis. The increase in number of flowers buds per stalk could

Table 1 Effect of spacing and plant growth regulators on number of flower buds per stalk of spider lily

Treatments	Year			Pooled
	2013-14	2014-15	2015-16	
A. Effect of spacing				
S_1 – 90 x 45 cm	16.52	16.41	15.47	16.13
S_2 – 60 x 60 cm	17.15	16.50	15.50	16.38
S_3 – 60 x 45 cm	16.59	17.07	16.12	16.59
S.Em±	0.103	0.11	0.12	0.19
CD at 5%	0.36	0.38	0.40	NS
B. Effect of PGR's				
T_1 -Gibberellic acid – 100 mg/l	15.95	16.00	15.01	15.65
T_2 - Gibberellic acid – 150 mg/l	16.88	16.86	15.85	16.53
T_3 - Gibberellic acid – 200 mg/l	19.58	18.67	17.67	18.63
T_4 - NAA – 50 mg/l	16.68	16.69	15.68	16.35
T_5 - NAA – 100 mg/l	15.78	15.76	14.83	15.45
T_6 - NAA – 150 mg/l	16.87	16.84	15.92	16.54
T_7 - Water Spray (control)	16.97	16.94	16.02	16.64
T_8 - No spray (control)	15.30	15.50	14.59	15.13
S.Em±	0.206	0.21	0.22	0.12
CD at 5%	0.58	0.61	0.62	0.34
Interaction				
S x T S.Em±	0.357	0.37	0.38	0.48
CD at 5%	1.01	1.06	1.08	NS
C.V.%	4.27	4.50	4.86	4.53
Y x S				Sig.
Y x T				NS
Y x S x T				Sig.

Table 2 Interaction effect of spacing and plant growth regulators on number of flower buds per stalk for the year 2013-14, 2014-15 and 2015-16

Plant growth regulators/		2013-14			2014-15			2015-16		
Spacing		S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
T_1 -Gibberellic acid – 100 mg/l		15.55	16.80	15.50	15.57	15.47	16.97	14.58	14.48	15.97
T_2 - Gibberellic acid – 150 mg/l		15.45	19.05	16.15	15.42	16.12	19.02	14.42	15.13	18.00
T_3 - Gibberellic acid – 200 mg/l		18.85	21.05	18.85	17.82	18.07	20.10	16.83	17.07	19.10
T_4 - NAA – 50 mg/l		16.90	16.10	17.05	16.92	17.02	16.12	15.93	16.03	15.10
T_5 - NAA – 100 mg/l		15.95	15.35	16.05	15.92	16.02	15.32	14.92	15.03	14.55
T_6 - NAA – 150 mg/l		16.75	16.70	17.15	16.72	17.12	16.67	15.97	16.10	15.67
T_7 - Water Spray (control)		17.40	16.50	17.00	17.37	16.97	16.47	16.60	15.98	15.48
T_8 - No spray (control)		15.30	15.65	14.95	15.47	15.17	15.87	14.48	14.17	15.12
S x PGR	S. Em±		0.357			0.37			0.38	
	C. D. at 5 %		1.01			1.06			1.08	
	C. V. %		4.27			4.50			4.86	
Y x S x T	S. Em±		0.37							
	C. D. at 5 %		1.03							

Interaction effect (Y x S) on flower buds per stalk of spider lily (Pooled)

Year/Spacing	S_1	S_2	S_3
Y_1	16.51	17.15	16.58
Y_2	16.40	16.50	17.07
Y_3	15.46	15.49	16.12
S. Em±	0.11		
C. D. at 5 %	0.33		

Table 3 Effect of spacing and plant growth regulators on number of stalk per clump of spider lily.

Treatments	Year			Pooled
	2013-14	2014-15	2015-16	
A. Effect of spacing				
S_1 – 90 x 45 cm	6.29	6.05	5.04	5.79
S_2 – 60 x 60 cm	6.06	6.31	5.30	5.89
S_3 – 60 x 45 cm	6.29	6.31	5.31	5.97
S.Em±	0.045	0.04	0.05	0.08
CD at 5%	0.16	0.15	0.17	NS
B. Effect of PGR's				
T_1 -Gibberellic acid – 100 mg/l	6.75	6.75	5.74	6.41
T_2 - Gibberellic acid – 150 mg/l	6.72	6.75	5.72	6.39
T_3 - Gibberellic acid – 200 mg/l	6.92	6.92	5.92	6.58
T_4 - NAA – 50 mg/l	6.32	6.35	5.35	6.00
T_5 - NAA – 100 mg/l	6.05	6.04	5.04	5.71
T_6 - NAA – 150 mg/l	6.20	6.22	5.21	5.87
T_7 - Water Spray (control)	5.45	5.46	4.47	5.12
T_8 - No spray (control)	5.32	5.30	4.30	4.97
S.Em±	0.097	0.10	0.10	0.06
CD at 5%	0.275	0.28	0.28	0.16
Interaction				
S x T S.Em±	0.168	0.17	0.17	0.09
CD at 5%	NS	NS	NS	NS
C.V.%	5.41	5.60	6.64	5.84
Y x S				Sig.
Y x T				NS
Y x S x T				NS

Interaction effect (Y x S) on No. of stalk per clump of spider lily (Pooled)

Year/Spacing	S_1	S_2	S_3
Y_1	6.29	6.06	6.28
Y_2	6.05	6.31	6.31
Y_3	5.04	5.30	5.31
S. Em±	0.05		
C. D. at 5 %	0.14		

Table 4: Effect of spacing and plant growth regulators on Bud length (cm) of spider lily

Treatments	Year			Pooled
	2013-14	2014-15	2015-16	of year
A. Effect of spacing				
S_1 – 90 x 45 cm	18.02	17.70	16.69	17.48
S_2 – 60 x 60 cm	17.71	18.00	17.07	17.59
S_3 – 60 x 45 cm	17.72	17.69	16.69	17.37
S.Em±	0.393	0.39	0.40	0.23
CD at 5%	NS	NS	NS	NS
B. Effect of PGR's				
T_1 -Gibberellic acid – 100 mg/l	18.50	18.47	17.45	18.14
T_2 - Gibberellic acid – 150 mg/l	18.24	18.23	17.23	17.90
T_3 - Gibberellic acid – 200 mg/l	18.17	18.17	17.17	17.84
T_4 - NAA – 50 mg/l	17.63	17.60	16.61	17.28
T_5 - NAA – 100 mg/l	17.63	17.60	16.61	17.28
T_6 - NAA – 150 mg/l	17.80	17.78	16.78	17.46
T_7 - Water Spray (control)	17.67	17.64	16.80	17.37
T_8 - No spray (control)	16.90	16.88	15.88	16.55
S.Em±	0.69	0.69	0.70	0.40
CD at 5%	NS	NS	NS	NS
Interaction				
S x T S.Em±	1.209	1.21	1.21	0.70
CD at 5%	NS	NS	NS	NS
C.V.%	13.56	13.60	14.39	13.84
Y x S				NS
Y x T				NS
Y x S x T				NS

be attributed to the increase in photosynthesis and respiration with enhanced carbohydrate fixation in GA_3 treated plants. This result is in conformity with the result obtained by Misra *et al* (2000) in lily and Nagaraja *et al* (1999), Singh (1999), Tak and Nagda (1999) in tuberose. The interaction effect of spacing and plant growth regulators on number of flower buds per stalk was found significant during all the years but, it was found non-significant in pooled analysis (Table 2). The treatment combination of T_3S_2 gave significantly the highest number of flower buds per stalk in the year 2013-14 and 2014-15. The interaction effect of Y x S and Y x S x T were also significant.

Number of stalk per clump

The data presented in Table 3 indicated that the individual effect of spacing on number of stalk per clump was found significant during the year 2013-14, 2014-15 and 2015-16. The significantly maximum number of stalk per clump was recorded with treatment of 60 x 45 cm spacing and 90 x 45 cm spacing as compared to 60 x 60 cm spacing in 2013-14. The significantly maximum number of stalk per clumps was recorded at a spacing of 60 x 60 cm and 60 x 45 cm in 2014-15 and 60 x 45 cm spacing in 2015-16. The effect of spacing on number of stalk per clump was found non-significant in pooled analysis. The individual effect of plant growth regulators on number of stalk per clump was found significant during the all the years and in pooled analysis. The maximum number of stalk per clump was recorded with gibberellic acid @ 200 mg/l as treatment as compared to other treatments of plant growth regulators during all the years and in pooled analysis.The interaction effect of spacing and plant growth regulators on number of stalk per clump was found non-significant during all the years as well as in pooled analysis. The interaction effect of Y x S was significant.

Bud length (cm)

The individual effect of spacing on bud length was found non-significant during all the years and in pooled analysis (Table 4). The individual effect of plant growth regulators on bud length was found non-significant during all the year and in pooled analysis. The higher bud length of spider lily was recorded in all the

Table 5 Effect of spacing and plant growth regulators on Fresh flower weight (g) of spider lily.

Treatments	Year			Pooled
	2013-14	2014-15	2015-16	
A. Effect of spacing				
S_1 – 90 x 45 cm	2.30	2.31	2.18	2.26
S_2 – 60 x 60 cm	2.34	2.22	2.12	2.22
S_3 – 60 x 45 cm	2.32	2.37	2.27	2.32
S.Em±	0.052	0.06	0.07	0.04
CD at 5%	NS	NS	NS	NS
B. Effect of PGR's				
T_1 -Gibberellic acid – 100 mg/l	2.31	2.27	2.08	2.22
T_2 - Gibberellic acid – 150 mg/l	2.29	2.30	2.20	2.26
T_3 - Gibberellic acid – 200 mg/l	2.47	2.47	2.37	2.46
T_4 - NAA – 50 mg/l	2.24	2.21	2.12	2.19
T_5 - NAA – 100 mg/l	2.31	2.28	2.18	2.26
T_6 - NAA – 150 mg/l	2.15	2.15	2.05	2.12
T_7 - Water Spray (control)	2.28	2.22	2.12	2.21
T_8 - No spray (control)	2.50	2.50	2.20	2.40
S.Em±	0.121	0.11	0.12	0.07
CD at 5%	NS	NS	NS	0.19
Interaction				
S x T S.Em±	0.210	0.200	0.210	0.120
CD at 5%	NS	NS	NS	NS
C.V.%	18.08	17.92	19.43	18.46
Y x S				NS
Y x T				NS
Y x S x T				NS

treatments of gibberellic acid as compared to other trearments of foliar spray. The increase in the bud length may be due to the cell elongation and cell division or both.This result is in accordance with the findings of Nagaraja *et al* (1999), Singh (1999) and Tak and Nagda (1999) in tuberose.

Fresh flower weight (g)

The data presented in Table 5 indicated that the individual effect of spacing on fresh flower weight was found non-significant during all the years and in pooled analysis. The individual effect of plant growth regulators on fresh flower weight was found non-significant during the year 2013-14, 2014-15 and 2015-16 but, it was significant in pooled analysis. The significantly maximum fresh flower weight (2.46 gm) was recorded with gibberellic acid @ 200 mg/l in pooled analysis. The increase in fresh flower weight might be due to attributable to the increased spike length and accumulation of more food material.

Number of flower bundles per hectare

The individual effect of spacing on number of flower bundles per hectare was found significant during all the years and in pooled analysis (Table 6). The significantly maximum number of flower bundles per hectare was recorded with treatment of spacing (60 x 45 cm) as compared to other spacing treatments. The individual effect of plant growth regulators on number of flower bundles per hectare was found significant during the all the years and in pooled analysis. The significantly maximum number of flower bundles per hectare (80562 in 2013-14, 76821 in 2014-15 and 62167 in 2015-16) were recorded with gibberellic acid @ 200 mg/l treatment as compared

Table 6 Effect of spacing and plant growth regulators on Number of flower bundles per hectare of spider lily

Treatments		Year			Pooled
		2013-14	2014-15	2015-16	
A.	Effect of spacing				
	S_1 – 90 x 45 cm	51533	57020	44794	51116
	S_2 – 60 x 60 cm	58224	63802	48976	57000
	S_3 – 60 x 45 cm	77747	68383	54379	66836
	S.Em±	708.47	1127.97	513.74	2945.07
	CD at 5%	2451.71	3903.43	1777.86	11561.93
B.	Effect of PGR's				
	T_1 -Gibberellic acid – 100 mg/l	64191	65432	52256	60627
	T_2 - Gibberellic acid – 150 mg/l	67775	69224	55303	64101
	T_3 - Gibberellic acid – 200 mg/l	80562	76821	62167	73183
	T_4 - NAA – 50 mg/l	63414	68725	50529	60889
	T_5 - NAA – 100 mg/l	57600	56516	44329	52815
	T_6 - NAA – 150 mg/l	63038	62616	49558	58404
	T_7 - Water Spray (control)	55336	55521	42879	51245
	T_8 - No spray (control)	48095	49693	38045	45277
	S.Em±	1133.72	2400.57	1228.41	975.07
	CD at 5%	3205.041	6786.44	3472.73	2702.75
Interaction					
S x T	S.Em±	1963.66	4157.91	2127.67	5939.18
	CD at 5%	5551.291	11754.47	6014.95	17159.72
	C.V.%	6.29	13.19	8.61	10.03
Y x S					Sig.
Y x T					NS
Y x S x T					Sig.

to rest of the treatments of plant growth regulators. This increase in yield might be due to the availability of desirable food materials and more carbohydrate supply which ultimately effects on flowers production. These results are in accordance with the findings of Khan and Tewari (2003) in dahlia; Maurya and Nagda (2002) in gladiolus and Tak and Nagda (1999) in tuberose. The interaction effect of spacing and plant growth regulators on number of flower bundles per hectare was found significant during all the years and in pooled analysis (Table 7). The interaction effects of Y x S and Y x S x T were also significant.

Vase life (hours)

The data presented in Table 8 revealed that the individual effect of spacing on vase life was found non-significant during the year 2014-15, 2015-16 and in pooled analysis but, it was significant in the year 2013-14. The significantly maximum vase life was recorded with treatment of spacing of 60 x 45 cm (17.01 hour) as compared to another spacing and which was at par with spacing of 60 x 60 cm (16.94 hour). The individual effect of plant growth regulators on shelf life was found significant during all the years and in pooled mean. The significantly maximum vase life (18.55 hrs in 2013-14, 18.61 hrs in 2014-15, 17.30 hrs in 2015-16 and 18.16 hrs in pooled) was recorded in treatment of gibberellic acid @ 200 mg/l as compared to rest of the treatments during all the years and in pooled analysis. The interaction effect of spacing and plant growth regulators on vase life was found non-significant during all the years and in pooled analysis.

CONCLUSION

The result obtain from the present investigation concluded that, spider lily crop grown at distance of 60 x 60 cm and two spray of Gibberellic acid @ 200 mg per litre was most effective treatment which improved the flower quality and increased the

Table 7 Interaction effect of spacing and plant growth regulators on number of flower bundles per hectare

Plant growth regulators/		2013-14			2014-15			2015-16		
Spacing		S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
T_1 -Gibberellic acid – 100 mg/l		52736	61345	78493	51059	58773	86465	40288	46940	69539
T_2 - Gibberellic acid – 150 mg/l		51462	71692	80171	52466	60032	95174	41504	47690	76715
T_3 - Gibberellic acid – 200 mg/l		65304	80044	96337	67475	92415	70573	54336	74655	57510
T_4 - NAA – 50 mg/l		55015	52528	82700	55539	97389	53248	43414	65882	42320
T_5 - NAA – 100 mg/l		46891	48642	77267	66896	52075	50577	51637	41313	40038
T_6 - NAA – 150 mg/l		50336	58456	80322	77487	54141	56219	62080	42458	44136
T_7 - Water Spray (control)		48748	48097	69163	45365	51786	69411	35038	39856	53744
T_8 - No spray (control)		41775	44986	57522	39873	43806	65402	30060	33042	51031
S x T	S. Em±		1963.66			4157.91			2127.67	
	C. D. at 5 %		5551.29			11754.47			6014.96	
	C. V. %		6.28			13.19			8.61	
Y x S x T	S. Em±		2925.21							
	C. D. at 5 %		8108.28							

Interaction effect (Y x S) on number of flower bundles per hectare of spider lily (Pooled)

Year/Spacing	S_1	S_2	S_3
Y_1	51533	58224	77747
Y_2	57020	63802	68383
Y_3	44794	48976	54379
S. Em±		824.25	
C. D. at 5 %		2449.07	

Table 8 Effect of spacing and plant growth regulators on Vase life (hours) of spider lily

Treatments	Year			Pooled
	2013-14	2014-15	2015-16	
A. Effect of spacing				
S_1 – 90 x 45 cm	16.14	16.62	15.41	16.11
S_2 – 60 x 60 cm	16.94	16.13	15.07	16.05
S_3 – 60 x 45 cm	17.01	16.83	16.00	16.65
S.Em±	0.167	0.10	0.21	0.23
CD at 5%	0.58	NS	NS	NS
B. Effect of PGR's				
T_1 -Gibberellic acid – 100 mg/l	16.38	16.60	15.31	16.10
T_2 - Gibberellic acid – 150 mg/l	17.15	17.16	15.67	16.66
T_3 - Gibberellic acid – 200 mg/l	18.55	18.61	17.30	18.16
T_4 - NAA – 50 mg/l	16.63	16.60	15.47	16.23
T_5 - NAA – 100 mg/l	15.71	16.27	15.14	15.71
T_6 - NAA – 150 mg/l	15.55	16.05	15.24	15.62
T_7 - Water Spray (control)	17.50	15.95	15.04	16.17
T_8 - No spray (control)	16.12	15.72	14.76	15.53
S.Em±	0.539	0.46	0.43	0.28
CD at 5%	1.52	1.32	1.23	0.77
Interaction				
S x T S.Em±	0.934	0.81	0.43	0.48
CD at 5%	NS	NS	NS	NS
C.V.%	11.19	9.75	9.71	10.27
Y x S				Sig.
Y x T				NS
Y x S x T				NS

Interaction effect (Y x S) on Vase life (hours) of spider lily (Pooled)

Year/Spacing	S_1	S_2	S_3
Y_1	16.14	16.94	17.01
Y_2	16.78	16.13	16.96
Y_3	15.40	15.07	16.00
S. Em±	0.17		
C. D. at 5 %	0.50		

flower yield of spider lily. Spraying of Gibberellic acids twice at 45 and 60 days after planting of bulb in first year and from second year onwards, spraying will be done at 45 an 60 days after cutting of leaves. Cutting of leaves will be done in the month of March.

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Estimated trend in production of cotton for Ahmedabad district of Gujarat state by statistical models

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ABSTRACT

An investigation was carried out using the polynomial (linear, quadratic and cubic) models were fitted on original data as well as three, four and five year moving averages data. The Autoregressive Integrated Moving Average (ARIMA) models were fitted to original time series data after checking the stationary condition, to arrive at a methodology that can precisely explain the fluctuation in production for cotton crop in Ahmedabad district of Gujarat for the period 1960-61 to 2014-15 (55 years) to compare different models. The error percentage for the selected model was also carried out to test the prediction power. The data from year 1960-61 to 2006-07 were used for model fitting and remaining year for testing the forecast. In polynomial models, the most suitable model was selected on the basis of R^2, significant regression coefficient, root mean square error, mean absolute error, normality (Shapiro and Wilk test) and randomness of residual's (Run test) distribution. The different ARIMA models (p, d, q) were judged on the basis of autocorrelation function (ACF) and partial autocorrelation function (PACF) at various lags. Among different fitted ARIMA models, the final models were selected on the basis of significant autoregressive and moving average term, Akaike's Information Criterion (AIC), Schwartz-Bayesian Criterion (SBC) and normality (Shapiro-Wilk test) and randomness of residual's (Run test) distribution. Suitable model for cotton production was in Ahmedabad district was ARIMA (1, 1, 0) with the lowest error percentage of prediction was during 2014-15 with 2.602% and highest during 2010-11 with 42.036%.

Key words: Shapiro and Wilk test, run test, polynomial model, ARIMA, autocorrelation function.

Cotton is one of the oldest and the most important commercial and fiber crop of the world. Cotton is referred to as " King of Fibres "and also known as "White Gold" It is heat loving and sun loving (heliophyte) plant. A daily minimum temperature of 16°C is required for germination and 21°C to 27°C for proper vegetative growth. It can tolerate temperature as high as 43° C, but does not do well if the temperature falls below 21° C. During fruiting phase, the day temperature ranging from 27° C to 30° C and cool nights are needed. Abundant sunshine during the crop growth period particularly the period of boll maturation and harvesting is essential to obtain a good quality produce. Successfully grown in areas receiving an average annual rainfall ranging from 500mm, of which 175-200 mm should be received during crop growth period. Cotton- Quality parameters-and yield attributes are categorised into (1) Colour of cotton fibre is white with few exceptions like desi cotton which have reddish or yellowish tinge. White coloured cotton which is shiny is considered as superior cotton. Cotton is grown in the nine major states in three different zones. Punjab, Haryana and Rajasthan in north zone; Maharashtra, Gujarat and Madhya Pradesh in central zone and Andhra Pradesh, Karnataka and Tamil Nadu in the south zone are the major cotton growing states. Central zone accounts for about 60 per cent of all cotton, and where only 16 per cent is irrigated. About 74 per cent of the total area and production of cotton in the country are contributed by four states of Gujarat, Andhra Pradesh, Maharashtra and Punjab. Cotton is mainly a rainfed crop in Gujarat. About 54 per cent of the state's produc-tion comes from Surendranagar, Rajkot, Vadodara, Ahmadabad and Sabarkantha districts. Other important producers include Mehsana, Bhavnagar, Bharuch, Kheda, Surat, Amreli and

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Panchmahals districts. The main long and medium stapled varieties include V-797, Digvijay, Sanjay, Kalyan, Dholleras, Deviraj, Wagad and Varalaxmi etc. Gujarat state accounts 17.10 lakh hectare area in 1960 and increases up to 30.6 lakh hectare area during year 2014-2015. Production of cotton crop increases 36.78 lakh bales to 125 lakh bale from year 1960 to 2014-2015. Productivity of cotton crop increases from 86 kg/hectare to 707 kg/hectare from year 1960 to 2014 -2015. (Anonymus, 2015b). The observation on these time series variables are varying in some pattern due to the existence of artificial and natural forces. But it is, indeed, a hard truth that policy makers, while formulating policies have to venture into the future (predicted) values of these time series variables for formulating the strategic all round developmental plan for zone or a state or a country. In literature, a large number of univariate time series models are available *viz.*, linear, polynomial, exponential, logistic *etc.* The model developed by Box and Jenkins during the seventies, popularly known as Autoregressive Integrated Moving Average (ARIMA) model, is often found to be superior among all above mentioned models in case of the univariate time series variables which are found correlated with their lag variables. The advantage of ARIMA modelling over the other univariate time series model is that besides displaying the intrinsic behaviour (generating process) in the time series variables itself, it produces the smallest mean squared forecast error variances. But as a mark of caution, it is noted that ARIMA models are useful only for forecasting the near future values destined to appear, usually, within the five years beyond the last datum observed on the time scale. Thus, in respect of given time series, the predicted values corresponding to the future time point considered in data set, cannot be relied upon. ARIMA model is an extrapolation method for forecasting and like any other such method, it requires only the historical time series data on the variables under forecasting. Among the extrapolation methods, this is one of the most sophisticated method, as it incorporates the future of all such methods, does not require the investigator to choose initial values of any variables and values of the various parameters a priori. It is robust to handle any data pattern. As one would expect this is quite a difficult model to develop and apply as it involves transformation of the variable, identification of the model, estimation through nonlinear method, verification of the model and derivation of the forecasts (Gupta, 1993).

The strength of ARIMA models lies in their ability to reveal complex structures of temporal interdependence in time series. It has also been shown that ARIMA models are highly efficient in short term forecasting (Fatimah and Gaffar, 1986).

Therefore, present investigation was undertaken to study the time series trend using data of cotton crop production Ahmedabad district by different statistical model. The data were obtained for Ahmedabad district during *kharif* session of 1960-60 to 2014-15 with following objectives.

i. To study fitting of Polynomial models for cotton crop in Ahmedabad district.
ii. To study fitting of ARIMA model for cotton crop in Ahmedabad district.
iii. To compare different models according to their ability of prediction.

MATERIALS AND METHODS

Considering the production of cotton crop for the period 1960-61 to 2014-15 the time series data were obtained from Directorate of Agriculture, Gujarat state, Gandhinagar and WHO Cell, Department of Agricultural Economics, College of Agriculture, J.A.U. The data from 1960-61 to 2006-07 were used for model fitting. Data from 2007-2008 to 2014-15 were used for testing of forecast.

Fitting of Polynomial models

(1) Linear Regression Approach (Rangaswamy, 2006)

The following proposed model was fitted to original data as well as moving average data as:

$$Y = a + bt \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, response or dependent variable Y was production, time variable (t) as independent variable and a, b are the regression constant and regression coefficient, respectively.

(2) Quadratic Regression Approach (Montgomery *et al.*, 2003)

The fitted regression equation for quadratic regression model for each of proposed districts was given as

$$Y=a + bt + ct^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The unknown parameter *viz.* a, b and c were estimated by using least square' method.

(3) Cubic Regression Approach (Montgomery *et al.*, 2003)

As for consideration of the third degree polynomial model fitted to the data of Ahmedabad district was

as under

$Y = a + bt + ct^2 + dt^3$ ..... (3)

The constant a and coefficient b, c and d were estimated using least square method.

(4) Goodness of fit of the models (Montgomery *et al.*, 2003)

The most common and widely used test statistics for the goodness of fit of the fitted polynomial models is coefficient of determination R^2 and it was calculated as under

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{n}(Y_i - \bar{Y})^2} \quad \text{and}$$

$$\text{Adj.}R^2 = 1 - \frac{(n-1)(1-R^2)}{(n-k)} \quad \ldots\ldots\ldots\ldots (4)$$

Where R^2 indicates the amount of variation in dependent variable accounted due to the model. For a given data set, it is well-known that R^2 is a non decreasing function of the number of parameters used. To overcome this weakness, an adjusted R^2 is proposed, since we interested in overall significance of the model. The F test was applied and the formula is given below.

$$F = \frac{R^2/k}{(1-R^2)/(n-k-1)} \quad \ldots\ldots (5)$$

Which follows F distribution with [k, (n-k-1)] degrees of freedom.

Where, n = number of observations

k = number of independent variables

The individual regression coefficients were tested using the t test under the null hypothesis, $\beta = 0$

$$t = \frac{b_i}{S.E.(b_i)} \quad \ldots\ldots (6)$$

t value with (n-k-1) degrees of freedom

Where b_i is estimated i^{th} coefficient and S.E. (b_i) is the standard error of b_i

For adequacy of fitted model, in addition to the above criteria, two more reliability statistics Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) were computed (*Liew et al.*, 2000). Both were computed by using the following formulae.

$$RMSE = \left[\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2/n\right]^{1/2} \quad \ldots\ldots\ldots (7)$$

$$\text{and } MAE = \sum_{i=1}^{n}\left|Y_i - \hat{Y}_i\right|/n \quad \ldots\ldots\ldots (8)$$

From the fitted models which had lower values of these estimates were considered better one.

According to Kvalseth (1985), before taking any final decision about the appropriateness of the fitted model, it is paramount importance to investigate the basic assumptions regarding the error term, *viz.*, randomness and normality.

(5) Test for the randomness of the residuals (Sidney and Castellan, 1988)

For the randomness of residuals *i.e.* it is independently distributed or in other word sample must be random to arrive at any conclusion about the population by using the information in the sample.

Suppose m be the number of positive sign residuals, considering one group of element and n be the number of negative sign residuals, being second group of element in sequence of N=m + n. To use sample run test, first observe the m and n events in which they occurred and determined the value of r (*i.e.* no. of runs). If m or n is larger than 20, Z value needs to calculate as under.

$$\text{Mean} = \mu = \frac{2mn}{N} + 1 \text{ and standard deviation} =$$

$$\sigma_r = \left[\frac{2mn(2mn-N)}{N^2(N-1)}\right]^{1/2} \quad \ldots\ldots (9)$$

$$Z = \frac{r - \mu_r}{\sigma_r} = \frac{r + h - \frac{2mn}{N} - 1}{\sqrt{\frac{2mn(2mn-N)}{N^2(N-1)}}} \quad \ldots\ldots (10)$$

$$\text{Where } h = +0.5 \text{ if } r < \frac{2mn}{N} + 1 \text{ and}$$

$$h = -0.5 \text{ if } r > \frac{2mnb}{N} + 1$$

Use normal table for testing Z value. The not significant Z value indicates randomness of the residual.

(6) Test for normality of the residual (Shapiro – Wilk, 1965)

To test for normality of the residual, The Shapiro - Wilk statistic is best suited among different test statistic to test the normality of residuals for time series data of above mentioned polynomial model and also in ARIMA model.

The required test statistics W was defined as

$$W = \frac{S^2}{b} \quad \text{Where} \quad S^2 = \sum a(k)\,[e(n+1-k) - e(k)]\,..(11)$$

The parameter k takes the value

$$k = \begin{cases} 1,2,3,4,.....n/2 & \text{when n is even} \\ 1,2,3,4,.....(n-1)/2 & \text{when n is odd} \end{cases}$$

and $b = \sum_{i=1}^{n} (e_i - \bar{e})^2$

The values of coefficients "a(k)" for different values of n and k are given (Shapiro - Wilk, 1965). When the calculated value of W is not-significant *i.e.* very close to unity, the null hypothesis regarding normality of residual was accepted.

Autoregressive (AR) and Moving Average (MA) models (Pankratz, 1983)

Talking on regression model, in ideal condition the parameters β's are assumed to be constant over the time. In the forecasting models the errors ε_t's within time period (t = I, 2, 3, . . . ,n) are assumed to be uncorrelated *i.e.* the observations Y_t's are uncorrelated and thus it is an independent and identically distributed sequence. However, this assumption is rarely happen in practice and general condition. Usually serial correlations in the observations often exist in time-series data, which is indication of stationarity of time series data. The statistical concept of autocorrelation was used to measure the relationships between the value of Z at time t (i.e., Y_t) and Y at earlier time periods (i.e., Y_{t-1}, Y_{t-2} ...). The algebraic forms of Autoregressive (AR) and Moving average (MA) processes are:

(1) Autoregressive (AR) process :

This model is in the same form as the well-known simple linear regression model in which $Y_t (Z_t)$ is the dependent variable and Y_{t-1} is the explanatory variable.

$$Z_t = C + \varphi_1 Y_{t-1} + a_t \quad .....(12)$$

Where Z_t= time sequenced random variable

C = constant term related to mean (μ) such that $C = \mu(1-\varphi_1)$

φ_1 = relationship of Y_t with Y_{t-1}

a_t = a random shock element at time t

A process involving past (time-lagged) Y terms is called an autoregressive (abbreviated as AR) process and the longest time lag associated with Y term is called the AR order of the process. The above equation is thus an AR process of order one, abbreviated as AR (1). Here it suffices to note that an AR (1) model implies that, conditional on the past return Y_{t-1}.

(2) Moving average (MA) process :

There are several ways to introduce MA models. One approach is to treat the model as a simple extension of white noise series. Another approach is to treat the model as an infinite-order AR model with some parameter constraints. We adopt the second approach. The general equation for moving average (MA) model was given as,

$$Z_t = c - \theta_1 a_{t-1} + a_t \quad ..... (13)$$

Where C = constant term related to mean μ and

θ = relation of a_t with a_{t-1}

The process with past (time-lagged) random shocks only are called moving average (abbreviated as MA) processes and the longest time lag associated with an error term (*i.e.* a_t) is called order of MA. The above equation is an MA process of order one, abbreviated as MA (1). For a pure MA model C=μ. The negative sign attached to θ_1 is merely a convention. It makes no difference whether to use negative or positive sign. The formula for calculating autocorrelation coefficient is :

$$\hat{\varphi}_{11} = r_1$$

$$\hat{\varphi}_{kk} = \frac{r_k - \sum_{j=1}^{k-1} \hat{\varphi}_{k-1,j}\, r_{k-j}}{1 - \sum_{j=1}^{k-1} \hat{\varphi}_{k-1,j}\, r_j} \quad \text{Where k = 1,2,3} \quad ..(14)$$

$$\text{and } \hat{\varphi}_{kj} = \hat{\varphi}_{k-1,j} - \hat{\varphi}_{kk}\,\hat{\varphi}_{k-1,k-j}$$

$$(k = 3,4,5,.....; j = 1,2,3,....,k-1$$

$\hat{\varphi}_{kk}$ = the estimate of the tru partial autocorelation coeffecient t φ_{kk}

$r_{k=}$ autocorrelation coefficient k lag apart

$\hat{\varphi}_{kj}$ = estimate of partial autocorrelation of coefficient t for lags apart when the effect of the intervenning lags has been removed

As long as data series is stationary the following set of recursive equation gives fairly good estimates of the partial autocorrelation

Fitting of Box-Jenkins ARIMA Models :

The AR or MA models discussed in the previous sections become cumbersome because one may need a high-order model with many parameters to adequately describe the dynamic structure of the data. To overcome this difficulty, the autoregressive moving-average (ARMA) models was introduced, most widely known as Box-Jenkins time-series models *i.e.* ARIMA (p, d, q) is known as "Univariate Box-Jenkins technique" (Box and Jenkins, 1976). An ARIMA model is an algebraic statement telling how observations on a variable are statistically related to past observation. To know whether data follow purely AR process or purely MA process or an ARMA process or an ARIMA process, BJ methodology comes in handy to answering preceding question.

This model includes three types of process, *viz.,* Autoregressive of order p; differencing to make a series stationary of degree d and moving average of order q. This method applied only to a stationary time series data. When the data is non-stationary then it has to be brought into stationary by the method of differencing.

(1) Test for Stationary

The foundation of time series analysis is stationarity. A time series $\{Y_t\}$ is said to be *strictly stationary* if the joint distribution of $(Y_{t1}, \ldots, Y_{tk})$ is identical to that of $(Y_{t+1}, \ldots, Y_{tk+t})$ for all t, where k is an arbitrary positive integer and (t1, . . . , tk) is a collection of k positive integers. The Stationarity requirement ensures that one can obtain useful estimates of the mean, variance and ACF from a sample. The Stationarity condition of a series was tested by examining the:

1. Change of mean and variance over time.
2. By the coefficients of AR and MA process i.e. in case of AR (1) and MA (1) process it should be $|\varphi_1| < 1$ and $|\theta| < 1$.
3. Estimated ACF values which should be tails-off towards zero rapidly.

The significance of autocorrelation was tested by t-test. The standard error of autocorrelation (Bartlett, 1946) was calculated as under

$$s(r_k) = \left(1 + 2\sum_{j=1}^{k-1} r_j^2\right)^{1/2} n^{-1/2} \qquad \ldots\ldots\ldots(15)$$

$$t_{r_k} = \frac{r_k - \rho_k}{S(r_k)} \qquad \ldots\ldots\ldots(16)$$

k=1, 2, 3...

The significant value of "t" indicates the presence of autocorrelation. The process of time series modelling involves transformation of data in order to achieve Stationarity, followed by identification of appropriate models, estimation of parameters, validation of models and finally for prediction. The complete description of these process and steps of time series modelling is clearly explained below.

RESULTS AND DISCUSSION

According to objective of the present research work, polynomial (Linear, Quadratic and Cubic) and ARIMA models were subjected to fitted on cotton production of Ahmedabad district of the Gujarat. The data were recorded for the year 1960-61 to 2014-15 from the published reports by the Directorate of Agriculture, Gujarat State, Gandhinagar and WHO cell, Department of Agricultural Economics J.A.U., Junagadh. The data from 1960-61 to 2006-07 were used for model fitting and remaining data from 2007-08 to 2014-15 were used for testing the forecast value of best fitted model among different selected model.

The different selected polynomial models (Linear, Quadratic and Cubic) were fitted to the original data as well as also on three years, four years and five years moving average data while Autoregressive Integrated Moving Average (ARIMA) models were fitted to the original data for cotton production of Ahmedabad districts. In fitting of Univariate Box-Jenkins (UBJ) Autoregressive Integrated Moving Average (ARIMA) models, the autocorrelation up to 12 lags were worked out for production of the Ahmedabad district. If the spikes did not sharply tails-off towards zero and if the visual inspection of the realization indicates that the mean, variance and autocorrelation were not constant over time then the series was considered as non-

Table 1 Fitted polynomial models for cotton production in Ahmedabad district

Model	Moving Average	Regression constant a	Regression coefficients b	c	d	Adj. R^2	RMSE	MAE	S-W Test	Run test(IZI)
Linear	Original	1586.960**	2.211	-	-	-2.0	647.264	471.996	0.953	2.653
	3 year	1568.424**	1.914	-	-	-2.1	484.179	362.200	0.974	3.581**
	4 year	1577.679**	0.664	-	-	-2.3	417.908	320.933	0.980	4.098**
	5 year	1494.223**	-5.725	-	-	-0.98	376.741	302.060	0.986	4.825**
Quadratic	Original	2372.833**	-94.015**	2.005**	-	22.7**	557.000	382.842	0.926	1.472
	3 year	2302.287**	-91.771**	2.003**	-	37.5**	374.393	280.774	0.955	5.029**
	4 year	2246.536**	-85.679**	1.929**	-	42.0*	310.780	243.182	0.966	5.025**
	5 year	2265.588**	-92.747*	2.141	-	58.6**	264.922	219.808	0.974	4.583**
Cubic	Original	2048.168**	-16.800	-1.971	0.055	23.9**	546.430	386.964	0.939*	0.587
	3 year	1931.638**	-0.080	-2.892	0.071*	42.0**	359.753	265.119	0.960	3.605**
	4 year	1923.715**	-5.039	-2.541	0.066*	47.5**	291.983	228.796	0.958	3.445**
	5 year	1922.868**	-7.965	2.417	0.066**	65.2**	247.005	202.079	0.966	3.618**

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

Table 2 Fitted ARIMA models for cotton production in Ahmedabad district

ARIMA	AIC	SBC	AR(ϕ)	MA(è)	CONS	RMSE	SW-TEST	BLQ- TEST
(1,1,0)	352.545	262.408	-0.303*	-	2.893	674.834	0.957	20.946
(1,1,1)	349.265	260.591	0.331	0.857**	4.412	625.967	0.944*	11.554
(2,1,0)	353.292	264.607	-0.350*,-0.141	-	5.700	675.591	0.946*	20.065
(3,1,0)	352.172	265.105	-0.391*,-0.251,-0.313*	-	9.492	648.438	0.943*	10.890

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

stationary. Therefore, the new variable X_t was constructed by taking difference of one (*i.e.* d = 1) to make the series stationary.

Fitting of trend on cotton production in Ahmedabad district:

(1) Fitting of polynomial models:

The results of fitted polynomial models are given in Table 1. The results indicated that all coefficients of determination (Adj. R^2) were significant in quadratic and cubic models and it was maximum (65.20) in cubic regression of five year moving average approach. All coefficients of determination (Adj. R^2) were negative in linear model for all data approaches. The regression constant values were found significant in all polynomial models of all approaches. None of linear regression coefficients were significant in linear and third degree polynomial models of all data approaches. The quadratic regression coefficients were significant in all approaches of second degree polynomial models. All linear regression coefficients of quadratic and cubic model were negative were as it was positive for linear model (except for five year moving data approach). In original data approach the value of Adj. R^2 were increased by 44.70 per cent in quadratic regression as compared to linear regression while, in case of cubic regression, it was 1.20 per cent over the quadratic model. By taking five years moving averages R^2 value was observed to be increased by 1.92, 30.90 and 41.30 percent in case of first, second and third degree polynomial models, respectively over original data.

(2) Fitting of ARIMA models:

As series was found non stationary, the new variable X_t was constructed by taking differences of one (*i.e.* d=1) to make the series stationary.

The autocorrelation function (ACF) and partial autocorrelation function (PACF) of various order of Xt were computed to identify the value of p and q. The ACF (Y_k) of the transformed variable was damping towards zero with cut off second and third's spike and the PACF (φ_{kk}) also cut-off at first lags. This suggested that the algebraic family of ARIMA on p =2 and 3 d=1 and q=1 can be used. The different models among the different value of p and q were fitted. Among the models, those models having lower value of AIC and SBC are given in Table 2. ARIMA (1, 1, 0) model had comparatively lower value of AIC and SBC with significant AR (φ) coefficient. The assumptions of residuals *i.e.* normality and independence of residuals were tested by Shapiro- Wilk test and Box-Ljung (Q) test indicated that all ARIMA models did not satisfied the assumption of normality (except ARMA(1,1,0) while all ARMA model satisfied the assumption of independent residuals.

Thus, for the production of cotton in Ahmedabad district none of the polynomial models were found satisfactory to explain the trend but ARIMA (1, 1, 0) was found satisfactory to explain the trend of cotton production in Ahmedabad district. Balanagammal *et al.* (2000) and found ARIMA (1,1,0) model which fulfilled all diagnostic criteria for prediction of cotton production in Tamilnadu Thus these results are similar to present investigation.

Table 3 Testing of forecast values for remaining eight years by using selected models *i.e.* ARIMA (1, 1, 0) of cotton production in Ahmedabad district.

Years	Observed Values	ARIMA (1,1,0)	
		Predicted values	Error Per cent
2007-08	2569	2466.281	3.998
2008-09	2682	2547.689	5.007
2009-10	3613	2744.557	24.036
2010-11	5920	3395.542	42.036
2011-12	3916	5223.151	-33.593
2012-13	5706	4703.492	17.573
2013-14	6123	5194.492	15.164
2014-15	6244	6081.493	2.602

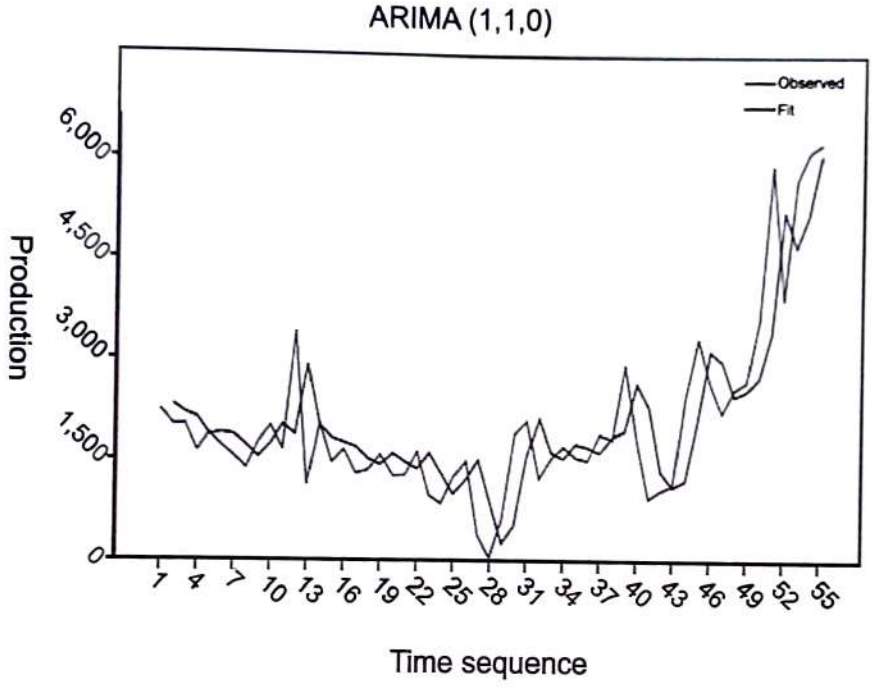

Fig. 1. Trend in cotton production based on ARIMA (1, 1, 0) models in Ahmedabad district

By using ARIMA (1, 1, 0), Predicted values and their error percentage are given in Table.3. The ARIMA (1, 1, 0) showed that during 2009-10 and 2010-11 it was over estimated and during 2011-12, it was underestimated while rest of year ARIMA (1, 1, 0) had good prediction for cotton production in Ahmedabad district.

CONCLUSION

The quadratic model on original data series from polynomial models was found suitable for fitting trend on production of Ahmedabad district. The production showed significant negative linear and positive quadratic trend. The fitted quadratic model for the production is

$\hat{Y}_t = 2372.833^{**} - 94.015^{**} t + 2.005^{**} t^2$ (Adj. R^2 =22.7%)

ARIMA (1, 1, 0) model fulfilled all the statistical requirement for being selected. The equation is

$\hat{Y}_t = 2.892 - 0.303^{**} Y_{t-1} + a_t$

The lowest error percentage of prediction was during 2014-15 with 2.602% and highest during 2010-11 with 42.036%.

It is suggested that the model based on original data with reasonably good R^2 can be used for future prediction while model based on moving averages can be used to predict average trend value. ARIMA models would be suitable only for short term prediction and hence need to be updated every year for achieving valid forecast.

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Effect of azolla supplemented feeding on milk production of crossbred milch animals

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ABSTRACT

The experiment was carried out to determine the effect of feeding azolla to crossbred milch animals. Experiment consists of 4 groups *viz.*, Group I (control devoid of azolla feeding), Group II (azolla 500 gm + grazing), Group III (azolla 500gm + concentrate feeding + green fodder), Group IV (azolla 1kg + concentrate feeding + green fodder). Azolla feeding trial was continued for 2 months. The two parameters *viz.*, milk yield and milk fat percentage were recorded and analysed. The milk yield and fat percentage recorded for Group III and Group IV milch animals were highly significant than Group II animals which were devoid of concentrate feeding. Twenty eight percentage replacement of concentrate feed with supplementation of 1 kilogram of azolla improved the milk yield to 800 ml/ day (11.4%) and 0.9 percent increase in milk fat (26%) compared to the control Group. The supplementation of 1 kilogram of azolla along with regular concentrates and green fodder to the crossbred milch animals has improvised the milk yield, milk fat percent and also a gain of extra profit to the farmers which in turn improves socio economic status of dairy farmers.

Key words: Azolla feeding, milch animals, milk, fat

Green fodder supplement is an important requirement in the feed for cattle. Even if the animals are fed with commercial feeds from the market, fresh green grass or dry straw is essential, as fodder availability greatly reduces the expenditure on commercial feeds. The success of a dairy plant depends largely on increasing milk production without escalation in feeding cost. Shortages of fodder are therefore being compensated with commercial feed, resulting in increased cost of meat and milk production. Moreover, as commercial feed is mixed with urea and other artificial milk boosters, it has a deleterious effect on the quality of milk produced and the longevity of the livestock, which in turn leads to degenerative diseases like cancer and coronary ailments in human beings. Fodder cultivation is a good option but it requires suitable land, ploughing, irrigation, fertilizers etc, cutting of fodder at regular intervals which is costlier. Thus suitable alternative fodder is Azolla cultivation and one hectare of *Azolla* can produce 540-720 kg of protein per month (Alcantara and Querubin,1985 ; Dao and Tran,1979).

Azolla is the most promising aquatic plant for livestock feed due to its ease of cultivation, productivity and nutritive value. Azolla has been used for many years to feed cattle, sheep, goats, pigs, ducks, chickens, fish and rabbits (Becerra *et al.*, 1995 ; Lumpkin and Plucknett,1982). Azolla has enormous potential as a livestock feed due to its high rate of growth in water without the need to displace existing crops or natural ecological systems. Azolla is also very rich in proteins, essential amino acids, vitamins (vitamin A, vitamin B12, Beta Carotene), growth promoter intermediaries and minerals including calcium, phosphorous, potassium, ferrous, copper, magnesium. On a dry weight basis, *azolla* has 25-35% protein content, 10-15% mineral content, and 7-10% comprising a combination of amino acids, bio-active substances and biopolymers (Kamalasanana *et al.*, 2002). Azolla's carbohydrate and oil content is very low. Azolla is also rich in iron (1000–8600 ppm dry weight), copper (3–210 ppm dry weight) manganese (120–2700 ppm dry weight), vitamin A (300–600 ppm dry weight.), chlorophyll and carotenes. It contains 4.8–6.7% dry weight crude fat, with 6.1–7.7% and 12.8–26.4% total fat for the polyunsaturated

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acids omega 3 and omega 6 (Paoletti *et al.*, 1987). Azolla's composition therefore makes it one of the most economic and efficient feed substitutes for livestock, particularly as can be easily digested by livestock due to its high protein and low lignin content. Keeping in view the advantages of feeding Azolla and management of fodder scarcity a study using Azolla supplement as cattle feed was taken up for cost effective feeding and improvement in milk production.

METHODOLOGY

Dairy farmers of Unnamalai village of Kancheepuram district of Tamilnadu were given proper training on azolla cultivation through Front Line Demonstrations. To study the impact of feeding azolla, 12 dairy farmers who have atleast two milch animals were chosen for the study and they were also educated on feeding azolla to milch animals. Selected cross bred Milch animals were fed with 0.5 – 1 kg azolla / day and Co-4 was given as green fodder (~10 kg) and approximately 3.5 kgs of concentrate feed mixture per day was also incorporated in the study group (n=6). The details of treatments are shown in Table 1. Harvested azolla was thoroughly washed with fresh water to remove the smell of dung before feeding the milch animals. Data on milk production and fat % was recorded for control and the treatment groups after 60 days of azolla feeding and the additional income generated through feeding azolla was also calculated. Statistical analysis was made using student's t-Test.

Table 1 Details of Treatments

Group (n=6)	Treatment
I	Control
II	Azolla 500 gm/ day + Grazing
III	Azolla 500 gm + Concentrate feeding (~3.5kg) + Green fodder (~10 kg) / day
IV	Azolla 1 kg + Concentrate feeding (~3.5kg) + Green fodder (~10 kg) / day

RESULTS AND DISCUSSION

Milk production (litres) and Milk fat percent before and after feeding azolla to milch animals of various groups were recorded. Data analysis revealed that Azolla feeding increased the Milk yield and increased the fat content of cows' milk as shown in Table 2. The results obtained were coinciding with Dinesan, (2007) and Biradar, (2007) who reported feeding Azolla improved milk production and quality of milk from dairy animals. The results of milk production and fat % of Group IV was significant ($p<0.05$) compared to Group III. However it was noteworthy to observe that the quantity of milk production and fat % obtained for Group III and Group IV milch animals were highly significant ($p<0.01$) compared to Group II animals. Group II (fat %), Milk production and fat % of Group III and Group IV were highly significant ($p<0.01$) whereas milk production of Group II was significant ($p<0.05$) compared to the control group devoid of azolla feeding.

Percentage increase in milk fat and quantity of milk after feeding azolla is represented in Fig. 1. The percentage increase of milk fat and milk yield of treatment groups was compared against control group. The increase in milk production was to the tune of 10 % and 11.4%, in Group III and IV, respectively whereas, it was only 4 % in group II which was not fed with concentrates and green fodder. Similarly 23% and 26% increase in the Milk fat percent was noticed in Group III and IV when compared to 8.5 % increase in group II. Feeding Azolla @ 1kg/day/ animal along with concentrate and green fodder had shown better result than treatment group II and group III. Therefore supplementing azolla as an alternate fodder in milch animals helped to increase the milk yield and milk fat %. Similar results were obtained by Manjunath patil *et al.*(2013) and Mathur *et al.* (2013).

The treatment groups (II,III,IV) supplemented with azolla had shown an increase in milk yield of 300-800 ml which was coinciding with the earlier reports of Manjunath patel *et al.*(2013) who also recorded 700 ml increase in milk production and Rawat Nidhi *et al.* (2015) also reported that feeding of azolla in cattle improved the production performance. In our study,

Table 2 Effect of azolla feeding on milk yield and fat percentage

Group (n = 6)	Treatment	Before feeding Azolla		After feeding Azolla	
		Fat (%)	Milk yield (lit)	Fat (%)	Milk yield (lit)
I	Control	3.6±0.051	6.9±0.032	3.5±0.041	7.0±0.052
II	Azolla 500 gm/ day + Grazing	3.5±0.055	7.1±0.042	3.8±0.031**	7.3±0.032*
III	Azolla 500 gm + Concentrate feeding (~3.5kg) + Green fodder (~10 kg) / day	3.6±0.033	7.0±0.042	4.3 ±0.045**	7.7±0.036**
IV	Azolla 1 kg + Concentrate feeding (~3.5kg) + Green fodder (~10 kg) / day	3.62±0.041	7.1±0.044	4.46±0.029**	7.8±0.036**

Note : 30 days average data. Control vs Group II, III and IV
*Significant p<0.05, **Highly Significant p<0.01

28% of concentrate feed was replaced with the same quantity of azolla which was in close agreement with Kamalasana *et al.* (2002) who replaced 15-20% of commercial feed with azolla without affecting milk production providing a 20-25% savings on buying commercial feeds.

Partial budgeting was done for the assessment of cost benefit ratio of azolla supplementation (Table 3) revealed that a farmer by investing ₹ 630/- on azolla production can earn net gain of ₹11000/- milch animal/ lactation indicating the high economic utility of this supplemental feeding. From the results it was evident that a saving of ₹ 20/- animal/day due to 28% replacement of azolla and an additional earning of ₹19/animal/day due to increase in quantity of milk. Similar results were quoted earlier by Kologi *et al.* (2009).

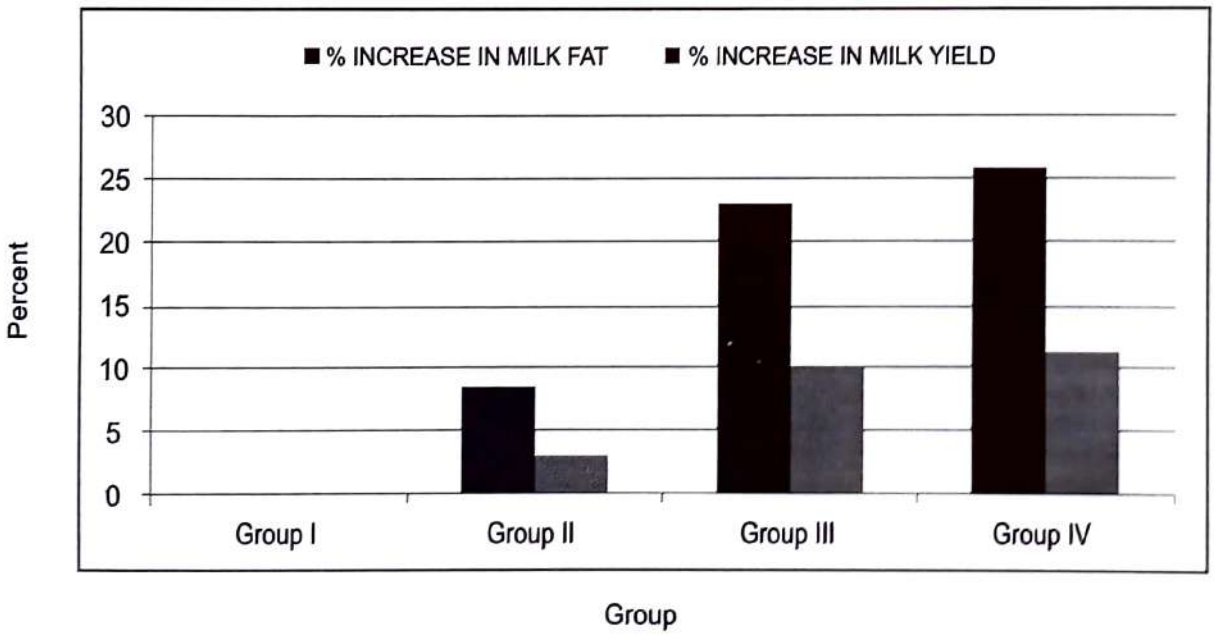

Fig. 1 Augmentation of fat percent and quantity of milk after azolla feeding

Table 3 Cost Benefit Ratio Analysis

No.	Particulars	Calculation	Amount (₹)
I	Increased milk yield 0.7 to 0.8 L/day/ animal For 30 days Cost of Milk @ ₹ 25/L (Procurement)	Avg 0.75L/day/animal 30 x 0.75= 22.5 L 22.5x25= ₹ 563/month ₹ 563 x 10 months (Lactation period)	5630.00
II	Reduction in concentrate feed cost 1 kg Azolla / animal/day Considering animal is yielding Avg.7 lit of milk/day, then it will consume ~3.5 kg concentrate/animal/day Replace concentrate feed with Azolla (1 kg per day) Cost of concentrate feed @ ₹ 20/ kg	3.5 kg x 300 days = 1050 kg / Lactation 1 kg x 300 days= 300 kg 300 kg x ₹ 20 Total (I + II)	6000.00 11630.00
III	Additional Cost	Additional cost ₹ 630.00 for making Azolla plot	630.000
IV	Economics Net gain= (Additional returns + Reduction in Concentrated Feed Cost) - Additional Cost		11000.00/ animal / lactation

CONCLUSION

Overall the study concluded that azolla supplement as an alternate fodder to milch animals improved the quantity and quality of milk. Azolla supplementation to milch animals @ 1 kg / animal / day is sufficient to improve the milk yield and milk fat percentage. Azolla feeding also reduce the feed cost and increase the profit.

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