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Combining ability and gene action for yield and yield components in sesame (*Sesamum indicum* L.)

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ABSTRACT

Combining ability for seed yield, yield components and oil content was studied in a 9 x 9 half diallel cross of sesame. Combining ability analysis revealed presence of both additive and non-additive gene actions for majority of the traits. The estimates of general combining ability effect suggested that parents GT 4 and AT 319 were good general combiners for seed yield per plant and its related attributes. The specific combining ability effect revealed AT 308 x SKT 12-2, GT 10 x GT 4 and AT 311 x SKT 12-2 as best specific combiners for seed yield per plant.

Key words : Sesame, combining ability, gca effect, sca effect

Sesame (*Sesamum indicum* L.) is one of the most important ancient and traditional oilseed crop and its seed contains 50 per cent oil and 25 per cent protein. It is sixth most important oilseed crop in India and cultivated in 18.6 lakh hectares area with 6.3 lakh tones production and productivity of 341 kg/ha. The yield improvement achieved through conventional hybridization followed by selection has been only marginal. Selection of parents in the hybridization programme is very important for getting the desirable recombinants for selection and to serve as parents for hybrids. Hence, the present investigation was undertaken to assess the nature of gene action involved in inheritance of yield and its contributing characters and to identify the best general combiners.

MATERIALS AND METHODS

The experimental materials comprised of 9 parents (*viz.*, AT 324, AT 311, AT 316, AT 314, AT 319, AT 308, GT 10, GT 4, SKT 12-2), their 36 hybrids produced through half diallel and one standard check *viz.*, GT 2. The experiment was laid out in a Randomized Block Design with 3 replications at Main Castor-Mustard Research Station, S. D. Agricultural University, Sardarkrushinagar during kharif-2014, with inter and intra-row spacing 45 and 15 cm, respectively. The observations were recorded on five competitive plants randomly selected from each genotype in each replication for days to flowering, days to maturity, plant height (cm), number of branches per plant, number of capsules per plant, number of seeds per capsule, seed yield per plant (gm), 1000 seed weight (gm), harvest index (%), oil content (%) and chlorophyll content.

The replication wise mean values of each genotype for various characters were subjected to statistical analysis as per the procedure of Randomized Block Design as suggested by Panse and Sukhatme (1985). Mean value of 46 entries (parents and hybrids) were entered in computer and combining ability analysis was carried out according to the procedure given by Griffing (1956a) as per Method II and Model I .The combining ability analysis was carried out as per the method suggested by Griffing (1956 a & b) Method-II, Model-1 which assumes that variety and block effects are constant. The chlorophyll content was measured at flowering stage of selected plant by using SPAD 502 meter (Minolta, 1989).

RESULTS AND DISCUSSION

The analysis of variance for combining ability for all the characters presented in Table1 revealed that the mean squares due to GCA as well as SCA were significant for all the characters except chlorophyll

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Table 1 Analysis of variance for combining ability for various characters in sesame

Source of variation	d.f.	Days to flowering	Days to maturity	Plant height (cm)	No. of branches per plant	No. of capsules per plant	No. of seeds per capsule	Seed yield per plant (g)	1000 seed weight (g)	Harvest Index (%)	Oil content (%)	Chlorophyll content
GCA	8	3.35**	18.81**	163.48**	8.59**	1207.87**	90.16**	6.87**	0.23**	25.76**	178.04**	9.99
SCA	36	0.82**	2.04*	181.81**	0.80**	271.26**	37.32**	2.71**	0.09**	44.70**	29.95**	3.09
Error	88	0.29	0.95	31.63	0.06	50.57	4.39	0.50	0.02	4.31	0.54	0.76
σ^2gca		0.28	1.62	11.99	0.78	105.21	7.80	0.58	0.02	1.95	16.14	0.84
σ^2sca		0.53	1.09	150.19	0.74	220.68	32.93	2.21	0.07	40.40	29.41	2.33
σ^2gca/ σ^2sca		0.53	1.49	0.08	1.04	0.48	0.24	0.26	0.27	0.05	0.55	0.36

* $P \leq 0.05$, ** $P \leq 0.01$.

Table 2 Estimates of general combining ability effect of parents for various characters

Sr. No.	Parents	Days to flowering	Days to maturity	Plant height (cm)	No. of branches per plant	No. of capsules per plant	No. of seeds per capsule	Seed yield per plant (g)	1000 seed weight (g)	Harvest Index (%)	Oil content (%)	Chlorophyll content
1	AT 324	0.51*	1.50**	2.64	-0.20*	-3.28	-1.29*	-1.10**	-0.20**	0.16	-9.51**	-1.75**
2	AT 311	-0.31*	0.83*	-4.47*	-1.00*	-4.11*	0.89	-1.29**	0.10*	0.50	-1.62**	-1.20**
3	AT 316	1.15**	1.53**	5.84**	2.05**	22.90**	-2.74**	0.31	-0.23**	0.88	2.09**	0.46
4	AT 314	-0.22	-0.68*	1.61	-0.19*	0.56	0.68	0.80**	0.04	0.92	1.64**	1.24**
5	AT 319	-0.01	0.95**	3.77*	0.33**	9.20**	-5.04**	0.91**	0.09*	-0.38	2.07**	0.21
6	AT 308	-0.19	-0.08	-3.36*	-0.07	-6.38*	0.63	0.56*	0.10*	1.11	0.33	-0.11
7	GT 10	0.21	-0.35	0.60	-0.73**	-7.76**	4.84**	0.20	0.08*	-1.16	4.85**	-0.08
8	GT 4	-0.58*	-2.02**	-5.24*	0.28**	0.692	2.41**	0.07	0.15**	1.46*	0.92**	0.29
9	SKT 12-2	-0.55*	-1.68**	-1.39	-0.49**	-11.83**	-0.37	-0.45*	-0.14**	-3.47**	-0.77**	0.94**
	S.E. (gi)	0.15	0.28	1.60	0.07	2.02	0.60	0.20	0.04	0.59	0.21	0.25

* $P \leq 0.05$, ** $P \leq 0.01$.

content indicating the importance of both additive and non-additive gene action in the inheritance of characters studied.

The ratio of GCA to SCA variance for various characters indicated that additive type of gene action was important in expression of days to maturity and number of branches per plant as the variance ratio was more than unity, whereas non-additive type of gene action was predominant in the expression of days to flowering, plant height, number of capsules per plant, number of seeds per capsule, seed yield per plant, 1000 seed weight, harvest index, oil content and chlorophyll content as the ratio of GCA to SCA variance was less than unity. Results are in agreement with the studies of Mishra and Yadav (1996), Kar *et al.* (2001), Sankar and Kumar (2003), Mothilal and Manoharan (2004), Shekhat *et al.* (2007), Misra *et al.* (2008), Raghunaiah *et al.* (2008), Parameshwarappa *et al.* (2010), Kumar *et al.* (2012) and Sarvaliya *et al.* (2013). The presence of predominantly large amount of non-additive gene action would necessitate the maintenance of heterozygosity in the population. Breeding methods such as biparental mating followed by reciprocal recurrent selection may increase frequency of genetic recombination and hasten the rate of genetic improvement.

The highest significant positive heterobeltiosis was recorded by the cross AT 308 × SKT 12-2 (67.90%) followed by AT 311 × SKT 12-2 (53.58%) and GT 10 × GT 4 (47.95%) for seed yield per plant. The GT 10 × GT 4 was the best hybrid for seed yield per plant, which registered significantly higher standard heterosis (43.75%) which is followed by AT 308 × SKT 12-2 (40.44%) than the check GT 2.

Nature and magnitude of combining ability effect helps in identifying superior parents and their utilization in further breeding programme. The close examination of GCA effect of the parents revealed that, none of the parents was found to be consistently good general combiner simultaneously for all the characters (Table 2). The parent GT 4 and SKT 12-2 were considered as good general combiners for earliness.

The parent GT 4 was good combiner for days to flowering, days to maturity, plant height, number of branches per plant, number of seeds per capsule, 1000-seed weight, harvest index and oil content. The parents, AT 319, AT 314 and AT308 were good general combiners for seed yield per plant. Among these, AT 319 was found to be best general combiner for seed yield per plant, and good general combiner for yield attributing characters i.e number of branches per plant, number of capsules per plant, 1000-seed weight and oil content. Therefore, parents, GT 4 and AT 319 can be considered as a good source of favourable genes for increasing seed yield along with other yield attributes and oil content and it would be worthwhile to use above parental lines in the hybridization programme. Vavdiya *et al.* (2013) also reported similar results in sesame.

The parents GT 10 and AT 316 were found to be good general combiners for oil content. Similarly, AT 314 and SKT 12-2 were found good general combiners for chlorophyll content. The results are similar to report of Saravanan and Nandarajan (2003).

The potentiality of a parent in hybridization may be assessed by it's *per se* performance and GCA effect. For the present study, top ranking parents for *per se* performance and GCA effect for different traits are presented in Table 3. The results revealed that the most of the characters had relatively high degree of correspondence between *per se* performance and GCA effect. This can be ascribed to the predominant role of additive and additive x additive type of gene action for the inheritance of these traits.

Three best crosses with significant SCA effects for various traits along with per se performance involved in the crosses are listed in Table 3. The crosses AT 324 × GT 10 and AT 316 × AT 308 showed significant negative SCA effect for days to flowering and day to maturity, these crosses can be used to isolate early flowering as well as maturity segregants in later generations. The best combinations AT 308 × SKT 12-2 and GT 10 × GT 4 expressed maximum SCA effect along with high per se performance, heterosis over better parent and check variety GT 2 for seed yield per plant as well as its contributing traits *viz.*, number of capsules per plant and number of seeds per capsules. The cross AT 311 × SKT 12-2 had significant SCA effect for seed yield per plant, number of branches per plant, number of seeds per capsules and chlorophyll content.

The cross AT 324 × AT 311 exhibited significant SCA effect for oil content and number of branches per plant and number of capsules per plant. The crosses which exhibited significant desirable SCA effect were AT 311

Table 3 Three top ranking parents with respect to per se performance and GCA effect; three top ranking hybrids with respect to per se performance and SCA effect and heterosis over better parent and check variety GT 2

Characters	Best performing parents	Best general combiners	Best performing hybrids	Hybrids with high SCA effects	SCA effects	Heterosis over	
						BP	SC- GT 2
Days to flowering	AT 311	GT 4	AT 316 x GT 4	AT 324 x GT 10	-1.46*	-	-0.91
	AT 308	SKT 12-2	AT 316 x AT 308	AT 316 x AT 308	-1.46*	-5.45*	-5.45*
	SKT 12-2	AT 311	AT 308 x SKT 12-2	AT 316 x AT 314	-1.25*	-3.70	-5.45*
Days to maturity	GT 4	GT 4	GT 4 x SKT 12-2	AT 324 x GT 10	-2.75*	-2.14	-
	SKT 12-2	SKT 12-2	AT 316 x GT 4	GT 10 x SKT 12-2	-2.56*	-	-0.75
	AT 314	AT 314	AT 316 x AT 308	AT 316 x AT 308	-2.35*	-1.12	-1.49
Plant height (cm)	AT 324	GT 4	AT 311 x SKT 12-2	GT 10 x SKT 12-2	-9.17	-	-
	GT 4	AT 311	AT 319 x GT 4	AT 316 x AT 314	-6.91	-	-
	AT 311	AT 308	AT 311 x AT 319	AT 314 x GT 4	-6.66	-	-
No. of branches per plant	AT 316	AT 316	GT 10 x GT 4	AT 324 x AT 311	2.24**	97.44**	57.14**
	AT 319	AT 319	GT 10 x AT 314	AT 311 x SKT 12-2	1.53**	47.62**	26.53*
	GT 4	GT 4	GT 10 x AT 316	GT 10 x AT 308	1.39**	-	108.16**
No. of capsules per plant	AT 316	AT 316	GT 10 x AT 316	GT 10 x AT 316	42.74**	72.87**	96.25**
	GT 4	AT 319	GT 10 x GT 4	AT 324 x AT 311	32.86**	67.48**	42.93**
	AT 319	GT 4	GT 10 x AT 319	GT 10 x AT 319	22.41*	41.43**	60.56**
No. of seeds per capsule	GT 10	GT 10	AT 308 x SKT 12-2	AT 311 x SKT 12-2	13.43**	19.86**	27.28**
	GT 4	GT 4	AT 311 x SKT 12-2	AT 308 x SKT 12-2	13.35**	9.47**	32.77**
	AT 314	AT 311	AT 319 x AT 308	GT 10 x AT 319	10.10**	12.29**	18.82**
Seed yield per plant (g)	AT 314	AT 319	GT 10 x GT 4	AT 308 x SKT 12-2	3.08**	67.90**	40.44**
	AT 308	AT 314	AT 308 x SKT 12-2	GT 10 x GT 4	2.75**	47.95**	43.75**
	AT 319	AT 308	AT 314 x GT 4	AT 311 x SKT 12-2	2.44**	53.38**	17.54
1000 seed weight (g)	GT 4	GT 4	AT 311 x AT 316	AT 311 x AT 316	0.83**	19.33**	29.21**
	AT 308	AT 311	AT 311 x AT 319	AT 324 x AT 316	0.55**	13.92*	12.94*
	AT 311	AT 308	AT 319 x SKT 12-2	AT 319 x SKT 12-2	0.50**	4.59	14.84**
Harvest Index (%)	AT 324	GT 4	GT 10 x AT 319	GT 10 x AT 319	13.33**	45.38**	36.54**
	AT 314	AT 308	AT 319 x GT 4	AT 311 x AT 314	8.55**	6.64	20.05**
	AT 311	AT 314	AT 324 x AT 319	GT 10 x SKT 12-2	8.37**	23.51**	12.86
Oil content (%)	GT 4	GT 10	AT 316 x AT 308	AT 324 x AT 311	8.70**	13.50**	-
	GT 10	AT 316	AT 308 x GT 4	AT 314 x AT 319	7.15**	18.04**	22.37**
	AT 314	AT 319	AT 314 x AT 319	GT 10 x AT 319	6.00**	22.84**	19.91**
Chlorophyll content	AT 314	AT 314	AT 314 x AT 319	AT 314 x AT 319	4.51**	28.69**	22.57**
	GT 4	SKT 12-2	GT 10 x AT 316	GT 4 x SKT 12-2	2.53*	14.21	16.82*
	AT 316	AT 316	GT 4 x SKT 12-2	AT 311 x SKT 12-2	2.33*	20.73*	5.60

* $P \leq 0.05$, ** $P \leq 0.01$; G = Good, A = Average, P = Poor.

× AT 316 for 1000 seed weight and GT 10 × AT 319 for harvest index, whereas cross AT 314 × AT 319 for chlorophyll content. The cross combination GT 10 × AT 316 exhibited significant SCA effect for number of capsules per plant.

In the present study, crosses which exhibited high SCA effects for yield per plant and other characters involved at least one good general combiner, indicated additive x dominance type of gene interaction, which could produce desirable transgressive segregates in subsequent generations.

CONCLUSION

Combining ability analysis revealed presence of both additive and non-additive gene actions for majority of the traits. The estimates of general combining ability effect suggested that parents GT 4 and AT 319 were good general combiners for seed yield per plant and its related attributes. The specific combining ability effect revealed AT 308 x SKT 12-2, GT 10 x GT 4 and AT 311 x SKT 12-2 as best specific combiners for seed yield per plant.

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Integrated nitrogen management in summer pearl millet [*Pennisetum glaucum* (L) R. Br. Emend Stuntz]

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ABSTRACT

An experiment was conducted at Agronomy Instructional Farm, C. P. College of Agriculture, SDAU, Sardarkrushinagar during summer, 2013 to study the effect of integrated nitrogen management in summer pearl millet. The experiment consisted of 10 different treatments of integrated nitrogen management practices for application of recommonded dose of nitrogen (RDN) to pear millet *i.e.* 160 kg/ha through different sources *viz.*, organic (FYM, vermicompost and castor cake), inorganic fertilizer alone or incombination with organic sources. The crop fertilized with 75 % RDN through fertilizer and 25 % RDN through either FYM or castor cake produced significantly higher growth parameters, grain yield (2948 kg ha^{-1}), straw yield (6248 kg ha^{-1}) and economics. The integration of nitrogen through inorganic and organic sources helped to sustain soil fertility.

Key words : Grain yield, straw yield, nitrogen, pearl millet

Pearl millet is one of the most important food grain crops of India and ranks fourth after rice, wheat and sorghum. In Gujarat, major pearl millet growing districts are Banaskantha, Mehsana, Patan and Kachchh. It is well adapted to production systems characterized by drought, low soil fertility and high temperature. Summer cultivation of pearl millet, particularly in the irrigated areas of North Gujarat has attracted the farmers because of the assurance of targeted crop yield. Integrated nutrient management involving soil resources, chemical fertilizers, bio-fertilizers and organic manures is the key to the sustained productivity as it reduces dependence on chemical fertilizers and not only improves fertilizer use efficiency, but also improves soil productivity by improving physical, chemical and biological properties of soil. The role of organic manures is well recognized and considered as balanced manures which supplies macro and micro nutrients which are essential for plant growth. It helps to build up the soil micro flora, which are useful to maintain the soil fertility. Microbial population increases more than five times with the application of vemricompost (Rout *et al.* 2001).

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MATERIALS AND METHODS

A field experiment was conducted on loamy sand soil, Agronomy Instruction Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during summer 2013. The experimental soil was loamy sand in texture, low in organic carbon (0.26%) and available nitrogen (158 kg ha^{-1}) and medium in phosphorus (50.4 kg ha^{-1}) and potassium (271 kg ha^{-1}) status. The experiment comprised of ten nitrogen management treatments viz. T_1 : 100% RDN through fertilizer, T_2 : 100% RDN through FYM, T_3 : 100% RDN through castor cake, T_4 : 100% RDN through vermicompost, T_5 : 75% RDN through fertilizer + 25% RDN through FYM, T_6 : 75% RDN through fertilizer + 25% RDN through castor cake, T_7 : 75% RDN through fertilizer + 25% RDN through vermicompost, T_8 : 50% RDN through fertilizer + 50% RDN through FYM, T_9 : 50% RDN through fertilizer + 50% RDN through castor cake and T_{10} : 50% RDN through fertilizer + 50% RDN through vermicompost were tried in randomized block design (RBD) with four replications. GHB 732 variety of pearl millet was sown at 45 cm row distance and 15 cm plant to plant distance with 3.750 kg ha^{-1}seed rate. A common application of 60 kg P_2O_5 ha^{-1} was applied to all plots after adjusting amount of phosphorus supplied by respective organic source.

Other agronomic practices were adopted as per recommendation of the crop. Observations on growth attributes at different stages, yield components and yield were recorded at harvest. Protein content and nutrient uptake as per standard procedure and economics of produce considering the local prevailing market price of inputs and output were also estimated. The data were statistically analysed and results were presented.

RESULTS AND DISCUSSION

The results (Table 1) indicated that different treatments had significant effect on growth and yield attributes as well as yield of pearl millet. Plant height at 30 DAS and at harvest was significantly influenced due to different nitrogen management treatments. Treatment T_5 (75% RDN - fertilizer + 25% RDN - FYM) recorded significantly higher plant height at 30 DAS (70.3 cm) and at harvest (158.5 cm), but remained at par with treatment T_6. Significant differences were observed in number of effective tillers per plant due to nitrogen management treatments. Application of 75% RDN - fertilizer + 25% RDN - FYM (T_5) recorded significantly higher number of effective tillers per plant (3.30), being at par with T_4 treatment. Integrated supply of nitrogen from organic and inorganic sources produced vigorous plants that ultimately resulted into better growth and development of crop.

Different nitrogen management treatments showed significant influence on yield attributes *viz.*, length of ear head, girth of ear head and grain yield per plant. Significantly higher length of ear head (23.5 cm) and girth of ear head (10.2 cm) were observed under treatment T_5, but it remained statistically at par with treatments T_6 and T_7. Application of 75% RDN - fertilizer + 25% RDN - FYM (T_5) produced significantly higher grain yield per plant (45.5 g). However, it was statistically at par with treatment T_6. Results further indicated that application of 75% RDN - fertilizer + 25% RDN - FYM (T_5) produced significantly higher grain (2948 kg ha^{-1}) and straw yields (6248 kg ha^{-1}), but remained statistically at par with treatments T_6 and T_7 in case of grain yield and treatment T_6 in case of straw yield, respectively. The increase in grain and straw yields under treatment T_5 was due to increased yield attributes which were enhanced with application of inorganic fertilizer in conjunction with organic sources like vermicompost, castor cake and FYM. Organic sources improved the physical condition of the soil apart from slowly releasing nutrients during entire crop growth period. Further, yield improvement was possible on account of better nutrient use efficiency. Similar findings were reported by Singh *et al.* (2013) and Damame *et al.* (2014).

Nitrogen is key element to improve the protein content of grain. Significantly higher protein content (11.42%) and protein yield (336.6 kg ha^{-1}) were registered when crop was fertilized with 75% RDN - fertilizer + 25% RDN - FYM (T_5). However, it remained statistically at par with treatments T_6 and T_7. Integrated supply of nitrogen through organic and inorganic sources enhanced the protein content in grain probably due to utilization of photosynthates in protein synthesis and its translocation to grains. Verma *et al.,* (2012) also reported similar results.

Various nitrogen management treatments had positive effect on soil fertility after harvest of the crop. Significantly higher organic carbon content (0.27%) in the soil after harvest of the crop was recorded under treatment T_4 (application of 100% RDN through vermicompost), but it remained statistically at par with treatment T_5. Significantly higher available nitrogen (183.4 kg ha^{-1}) was registered under treatment T_4 (100% RDN through vermicompost). However, it remained statistically at par with treatments T_5 and T_3. All the treatments failed to exert significant influence on available phosphorus content in the soil after harvest of crop. The increased organic carbon and available nitrogen under organic treatments might be due to addition and decomposition of organic matter and greater multiplication of soil microbes which could convert organically bound nitrogen in available form leading to build up of high available nitrogen. Present results are in line with the findings reported by Patil *et al.* (2006).

A perusal of economics data indicated that the highest net return of ₹ 49896 ha^{-1} with BCR of 4.08 was registered under treatment T_1 (100% RDN through fertilizer) which was closely followed by treatments T_6 (net return of ₹ 48980 ha^{-1} and BCR of 3.35) and T_5 (net return of ₹ 48962 ha^{-1} with BCR of 3.18).

CONCLUSION

Looking to the results obtained from the presented investigation, it can be concluded that for securing higher grain and straw yield, net realization and maintain soil fertility under North Gujarat agro-climatic conditions on loamy sand soil, summer pearl millet

Table 1 Effect of different nitrogen management treatment on yield attributes and yield of pearl millet

Treatment	Plant height (cm)		Effective tillers/ Plant	Ear head length (cm)	Girth of ear head (cm)	Grain yield per plant (g)	Yield (kg/ha)	
	30 DAS	At harvest					Grain	Straw
T_1: 100% RDN through fertilizer	65.5	145.8	2.78	21.1	9.1	43.2	2730	5745
T_2: 100% RDN through FYM	60.2	146.3	2.88	21.8	9.6	43.6	2804	5850
T_3: 100% RDN through castor cake	58.1	146.2	2.98	22.8	9.6	43.8	2802	5865
T_4: 100% RDN through vermicompost	67.5	147.0	3.08	21.8	9.4	42.8	2687	5813
T_5: 75% RDN through fertilizer + 25% RDN through FYM	70.3	158.5	3.30	23.5	10.2	45.5	2948	6248
T_6: 75% RDN through fertilizer + 25% RDN through castor cake	67.3	153.4	2.95	23.0	10.0	45.0	2894	5987
T_7: 75% RDN through fertilizer + 25% RDN through vermicompost	66.3	152.0	2.98	22.8	9.7	43.5	2856	5904
T_8: 50% RDN through fertilizer + 50% RDN through FYM	61.0	150.3	3.03	21.7	9.4	43.9	2675	5968
T_9: 50% RDN through fertilizer + 50% RDN through castor cake	58.5	149.0	2.90	22.0	9.5	43.8	2696	5949
T_{10}: 50% RDN through fertilizer + 50% RDN through vermicompost	62.8	148.4	2.90	22.0	9.6	43.4	2794	5958
S.Em ±	1.2	2.2	0.08	0.39	0.20	0.40	48.1	90.5
C.D	3.1	6.1	0.23	1.13	0.57	1.17	139.6	262.8
C.V %	6.61	2.78	5.27	3.91	4.06	1.84	3.45	3.05

Table 2 Effect of different nitrogen management treatment on quality of pearl millet, nutrient status in soil and net return

Treatment	Protein content in grain (%)	Protein yield (kg/ha)	O.C. (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Net return (₹/ha)	BCR
T_1: 100% RDN through fertilizer	11.20	305.7	0.22	146.1	50.1	49896	4.08
T_2: 100% RDN through FYM	10.83	303.6	0.24	168.7	51.2	26391	1.64
T_3: 100% RDN through castor cake	10.77	301.7	0.24	170.4	51.9	32831	1.94
T_4: 100% RDN through vermicompost	10.64	285.8	0.27	183.4	52.6	5607	1.09
T_5: 75% RDN through fertilizer + 25% RDN through FYM	11.42	336.6	0.26	176.5	50.6	48962	3.18
T_6: 75% RDN through fertilizer + 25% RDN through castor cake	11.31	327.3	0.24	154.9	50.9	48980	3.35
T_7: 75% RDN through fertilizer + 25% RDN through vermicompost	11.28	322.1	0.24	164.4	50.6	41844	2.54
T_8: 50% RDN through fertilizer + 50% RDN through FYM	10.61	283.8	0.24	162.1	50.1	36645	2.27
T_9: 50% RDN through fertilizer + 50% RDN through castor cake	10.55	284.4	0.24	161.7	50.7	40251	2.57
T_{10}: 50% RDN through fertilizer + 50% RDN through vermicompost	10.45	291.9	0.24	159.3	50.3	29823	1.79
S.Em ±	0.19	7.85	0.01	4.52	1.02	–	–
C.D	0.55	22.77	0.02	13.32	NS	–	–
C.V %	3.50	5.17	12.07	12.34	3.99	–	–

(GHB 732) crop may be fertilized by 75% RDN through inorganic fertilizer and 25% RDN through either FYM or castor cake. The integration of nitrogen through inorganic and organic sources helped to maintain soil fertility.

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Effect of integrated phosphorus management on yield, uptake and quality of fenugreek [*Trigonella foenum-graecum* L.]

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ABSTRACT

A field experiment was conducted during *rabi* 2014-15 at Agronomy Instructional Farm, C.P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, to study the 'Effect of integrated phosphorus management on yield, uptake and quality of fenugreek'. The experiment consisted of 10 different treatments of integrated phosphorus management practices for application of recommended dose of phosphorus (RDP) to fenugreek i.e. 40 kg/ha through different sources *viz.*, control, organic [vermicompost (VC) and castorcake (CC)], inorganic fertilizer alone or in combination with organic sources and PSB. Results revealed that integration of 50% RDP through vermicompost + 50% RDP through inorganic fertilizer along with seed inoculation of PSB recorded higher seed yield and straw yield as well as significantly improved the microbial population of *rhizobium* and PSB in the soil after harvest of the crop as compared to rest of the treatments. Combined application of 50% RDP through vermicompost + 50% RDP through inorganic fertilizer + PSB inoculation registered higher P content, total uptake of nitrogen and phosphorus by fenugreek over control and application of organic manure and inorganic fertilizer alone surpassed rest of the treatments. It was also proved best treatment for getting maximum net profit and BCR. Different phosphorus management treatments failed to produce significant influence on protein content.

Key words : Castor cake, economics, rhizobium, vermicompost

Fenugreek popularly known as by its vernacular name "methi' is an important condiment legume crop grown in Northern India concentrated in Rajasthan and Gujarat states. The seeds of fenugreek are used in chronic dysentery, chronic diarrhea and cough, enlargement of lever, diabetic, spleen and rickets. Its seeds are also used to induce lactation during post natal period. Looking to the importance of fenugreek among spices and condiments, it may be called as queen of seed spices.

Phosphorus is backbone of energy related activities and development of root system. Most of the Indian soils have inadequate supply of phosphorus hence need to supplement P in the form of fertilizer for optimum crop production. Application of organic manure in conjunction with inorganic fertilizer in an integrated manner appears to be the best alternative. Integrating chemical fertilizer with organic manures has been found to be quiet promising not only in maintaining higher productivity but also in providing great stability in crop production (Nambiar and Abrol, 1989).

Integrated phosphorus management has assumed greater significance in the recent past mainly because of two reasons. First, the continuous increase in agricultural production with shrinking land resources requires increased level of fertilizer and present level of fertilizer production in India is not enough to meet the total plant nutrients requirement. The gap between demand and supply of fertilizers was about 3.5 million tonnes in 2012-13. Secondly, the results of large number of experiments on manure and fertilizers conducted in the country revealed that neither chemical fertilizers nor organic manures alone exclusively can achieve the production sustainability of soil as well as crop. Even balanced use of chemical fertilizer will not be able to sustain high productivity due to the emerging deficiency of one or more of

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secondary and micronutrients (Hedge and Sarkar, 1990). The combined use of organic and inorganic sources of nutrients in an integrated way found superior to the use of each component separately. Keeping in view present study was undertaken to study the effect of integrated phosphorus management on yield, uptake and quality of fenugreek (*Trigonella foenum-graecum* L.)

MATERIALS AND METHODS

A field experiment was conducted during *rabi* 2014-15 at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar to study the effect of integrated phosphorus management on yield, uptake and quality of fenugreek (*Trigonella foenum-graecum* L.)". The soil of the experimental plot was loamy sand containing 149, 39.60 and 188 kg/ha available nitrogen, phosphorus and potassium, respectively in 0-15 cm soil depth with pH 8.0 and organic carbon 0.27 per cent. There was 10 treatments *viz.*,T_1: control i.e. 20 kg N/ha through inorganic fertilizer (urea), T_2 : 100 % RDP through vermicompost, T_3 : 100% RDP through castor cake, T_4:100 % RDP through inorganic fertilizer, T_5: 50% RDP through vermicompost + 50% RDP through castorcake, T_6: 50% RDP through vermicompost + 50% RDP through castor cake + PSB, T_7: 50% RDP through vermicompost + 50% RDP through inorganic fertilizer, T_8: 50% RDP through castor cake + 50% RDP through inorganic fertilizer,T_9 : 50% RDP through vermicompost + 50% RDP through inorganic fertilizer + PSB and T_{10}: 50% RDP through castor cake + 50% RDP through inorganic fertilizer + PSB were evaluated in randomized block design with four replications. The recommended dose of nitrogen (20 kg/ha) was applied through urea at basal. While phosphorus through single super phosphate, vermicompost and castor cake were applied at basal as per treatments. Castor cake was applied 10 days before sowing of fenugreek in previously opened furrow as per treatments. Quantity of castor cake and vermicompost added in treatments was determined by considering the phosphorus content in castor cake (0.8 %) and vermicompost (1.3 %). For studying the growth and yield attributes five plants were tagged randomly in the net plot. Yield and yield attributes were recorded at harvest under different treatments. The cost of cultivation and returns were calculated by taking into account the prevailing cost of inputs and prices of produce.

Estimation of N and P content in seed and straw of fenugreek was done by using Kjeldhal method (Waranke and Barber, 1974) and Vanado molydophosphoric acid yellow colour method (Jackson, 1973), respectively. The uptake of nitrogen and phosphorus in seed and straw were determined by using the following formula.

Total nutrient uptake (kg/ha) = [Nutrient content in seed (%) x Seed yield (kg/ha)] + [Nutrient content in straw (%) x Straw yield (kg/ha)]

The protein content in seed was calculated by multiplying nitrogen content of the seed (per cent) with the factor 6.25 as reported by Gupta *et al.*, (1972) and was expressed as percentage of protein content. Count of *rhizobium* and PSB in soil after harvest of crop were analyzed by Spread (Pour) plate method.

RESULTS AND DISCUSSION

Seed and straw yields

The application of phosphorus through various sources along with biofertilizer (PSB) significantly influenced seed and straw yields over control (Table 1). The maximum seed (1895 kg/ha) and straw (3638 kg/ha) yields of fenugreek were recorded by the application of 50% RDP through vermicompost + 50 % RDP through inorganic fertilizer + PSB inoculation (T_9) and was found statistically at par with 50% RDP through castor cake + 50% RDP through inorganic fertilizer with and without PSB (T_8 & T_{10}) but significantly superior over rest of the treatments (Table 1). In comparison to control and sole application of organic manures and inorganic fertilizer, an additional seed yield of 464 to 776 kg/ha and straw yield of 990 to 1475 kg/ha were obtained with conjunctive use of organic manure + inorganic fertilizer with biofertilizer i.e. 50% RDP through vermicompost + 50% RDP through inorganic fertilizer + PSB, which might be due to direct application of an appreciable amount of essential plant nutrients through organic manures and improvement in physical properties of the soil (Nambiar and Abrol, 1989). Higher yield in this treatment might be due to cumulative effect of elevated growth as well as yield structure. The results supported by the findings of Wagadre *et al.*, (2010).

Nitrogen and Phosphorus content and uptake

Integrated application of phosphorus failed to reach the level of significance with respect to nitrogen content in seed and straw and P content in straw

Table 1 Yield, protein content, microbial population and economics as influenced by different treatments

Treatment	Seed yield (kg/ha)	Straw yield (kg/ha)	Protein content (%)	Rhizobium (CFU x 10^8/g soil)	PSB (CFU x 10^8/ g soil)	Cost of cultivation (₹ /ha)	Net return (₹ /ha)	BCR
T_1 : Control (20 kg N/ha through urea)	1119	2163	19.74	4.78	5.18	28194	39840	2.41
T_2 : 100% RDP through vermicompost	1431	2648	19.95	5.47	5.49	44323	42326	1.95
T_3:100% RDP through castorcake	1188	2259	19.66	5.46	5.48	47878	24239	1.51
T_4 : 100% RDP through inorganic fertilizer	1361	2499	20.11	5.52	6.52	29619	52733	2.78
T_5 : 50% RDP through vermicompost + 50% RDP through castorcake	1606	3139	20.18	6.08	6.58	46101	51646	2.12
T_6 : 50% RDP through vermicompost + 50% RDP through castor cake +PSB	1570	2928	20.20	6.24	6.75	46181	48953	2.06
T_7 : 50% RDP through vermicompost + 50% RDP through inorganic fertilizer	1577	3209	20.49	6.20	6.71	36864	59498	2.61
T_8 : 50% RDP through castorcake + 50% RDP through inorganic fertilizer	1753	3374	20.61	6.16	6.66	38641	67896	2.76
T_9 : 50% RDP through vermicompost + 50% RDP through inorganic fertilizer + PSB	1895	3638	21.05	6.64	7.19	36944	78195	3.12
T_{10}: 50% RDP through castorcake + 50% RDP through inorganic fertilizer + PSB	1786	3526	21.03	6.31	6.83	38722	70086	2.81
S.Em. ±	54.7	138.8	0.39	0.27	0.21	-	-	-
CD (P = 0.05)	158.7	402.8	NS	0.78	0.60	-	-	-
CV (%)	7.16	9.43	3.83	9.10	6.53	-		
Initial microbial population	-	-	-	4.91	4.23	-	-	-

Table 2 Nutrient content and uptake by fenugreek as influenced by different treatments

Treatment	N content (%)		P content (%)		Nitrogen uptake (kg/ha)			Phosphorus uptake (kg/ha)		
	Seed	Straw	Seed	Straw	Seed	Straw	Total	Seed	Straw	Total
T_1 : Control (20 kg N/ha through urea)	3.16	0.42	0.19	0.14	35.36	9.08	44.48	2.12	3.02	5.25
T_2 :100% RDP through vermicompost	3.19	0.42	0.21	0.14	45.64	11.12	56.93	3.00	3.70	6.77
T_3 : 100% RDP through castor cake	3.15	0.43	0.21	0.15	37.42	9.71	46.98	2.49	3.38	5.75
T_4 : 100% RDP through inorganic fertiliizer	3.22	0.43	0.21	0.15	43.82	10.49	54.44	2.85	3.74	6.51
T_5 : 50% RDP through vermicompost + 50% RDP through castor cake	3.23	0.43	0.21	0.14	51.87	13.49	65.24	3.37	4.39	7.92
T_6 : 50% RDP through vermicompost + 50% RDP through castor cake + PSB	3.23	0.43	0.21	0.15	50.71	12.59	63.27	3.29	4.39	7.71
T_7 : 50% RDP through vermicompost + 50% RDP through inorganic fertilizer	3.28	0.43	0.22	0.15	51.72	13.79	65.56	3.46	4.81	8.16
T_8 : 50% RDP through castor cake + 50% RDP through inorganic fertilizer	3.30	0.44	0.22	0.15	57.84	14.83	72.60	3.85	5.06	8.90
T_9 : 50% RDP through vermicompost + 50% RDP through inorganic fertilizer + PSB	3.37	0.44	0.23	0.15	63.86	16.09	80.23	4.35	5.45	9.98
T_{10} : 50% RDP through castor cake + 50 % RDP through inorganic fertilizer + PSB	3.37	0.44	0.22	0.15	60.18	15.51	75.71	3.92	5.28	9.27
S.Em. ±	0.06	0.01	0.004	0.003	2.01	0.64	2.29	0.19	0.23	0.32
CD (P = 0.05)	NS	NS	0.01	NS	5.84	1.87	6.65	0.38	0.68	0.93
CV (%)	3.83	2.98	3.53	3.45	8.11	10.13	7.33	7.99	10.84	8.39

(Table 2). Marked differences were observed in P content of seed due to different P management treatments. Application of 50% RDP through vermicompost + 50% RDP through inorganic fertilizer + PSB noted significantly higher P content (0.23) in seed being at par with treatments T_7, T_8 and T_{10}. Increase in P content was to the tune of 15.78 per cent over control These findings are in agreement with those reported by Wagadre *et al.* (2010) and Mehta *et al.* (2012).

Total nitrogen and phosphorus uptake by plant were significantly influenced due to different integrated phosphorus management treatments (Table 2). An application of 50% RDP through vermicompost + 50% RDP through inorganic fertilizer + PSB considerably increased total nitrogen uptake (80.23 kg/ha) and phosphorus uptake (9.98 kg/ha) being found at par with treatment T_{10}. As compared to control, the per cent increase in total nitrogen uptake was 80.37 and 70.21 per cent due to treatments T_9 and T_{10}, respectively. Similarly phosphorus uptake was higher by 90.09 and 76.57 per cent under treatments T_9 and T_{10}, respectively against control treatment. These results are in close conformity with the findings of Khiriya and Singh (2003), Singh *et al.* (2010), and Mehta *et al.* (2012).

The application of vermicompost and castor cake resulted in the formation of carbon dioxide which plays an important role in the solubilization of native P and reduces phosphate fixing capacity of the soil. These action of organic manures resulted into higher P content in seed of fenugreek. It is established fact that nutrient uptake by the crop depends primarily on dry matter accumulation and secondarily on the nutrient content at cellular level. The increased total dry matter production and nutrient content seems to be the major cause responsible for higher N and P uptake of integrated nutrient management.

Protein content

Different integrated phosphorus management treatment did not differ significantly with respect to protein content in seed. This might be due to no significant improvement in nitrogen content (Table 1)) in seed due to different P management treatments in present study. On the contrary to these results, Wagadre *et al.* (2010) observed significant increase in protein content in fenugreek seed.

Microbial population of rhizobium and PSB

Population of soil microbes *viz.*, *rhizobium* and PSB after harvest of crop were improved significantly due to different treatments of integrated phosphorus management (Table 1). Among different treatments, an application of 50% RDP through vermicompost + 50% RDP through inorganic fertilizer + PSB (T_9) exerted its notable impact on increment of population of *rhizobium* (6.64 CFU x 10^8/g soil) and PSB (7.19 CFU x 10^8/g soil) after harvest of crop over control (T_1) and sole application of organic manures (T_2 & T_3) and inorganic fertilizer (T_4) but statistically remained at par with treatments T_5, T_6, T_7, T_8 and T_{10}. The percent increase in population of *rhizobium* and PSB after harvest were 38.91 and 37.24 per cent under treatment T_9 over control treatment (T_1). Integration of sources of nutrients viz; organic, inorganic and biofertilizers application facilitated robust growth of plants and soil health and thereby increased in nodulation. Increasing in nodulation is directly related to increase in microbial population in soil. Similar findings have been reported by Bhatt (2011).

Economics

Integrated management of phosphorus had significant influence on economics of fenugreek. The maximum monetary net return of ₹ 78195/ha with BCR (3.12) were obtained with application of 50% RDP through vermicompost + 50% RDP through inorganic fertilizer + PSB (Table 1) closely followed by application of 50% RDP through castor cake + 50% RDP through inorganic fertilizer + PSB. This could be attributed due to higher seed and straw yield received in these treatments. These findings are in accordance with those reported by Singh *et al.* (2010) and Mehta *et al.* (2012).

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Effects of weed management practices on growth, yield and economics of fennel (*Foeniculum vulgare* Mill.)

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ABSTRACT

An experiment was conducted during *rabi* season of 2011-12 at S.D. Agricultural University, Sardarkrushinagar to find out economically viable method of weed control in fennel (*Foeniculum vulgare* Mill.). The experiment was laidout in randomized block design with four replications. Results revealed that besides weed free treatment significantly the highest plant height at all the growth stages, number of branches per plant, yield attributes such as number of umbels per plant, number of umbellates per umbel, number of seeds per umbellate, seed and straw yields of fennel were recorded with application of Pendimethalin @ 0.75 kg/ha as PE + HW at 45 DAS being at par with the treatment of HW and interculturing at 25 DAS + 45 DAS. Similarly, the lowest dry weight of weeds at harvest and weed index as well as weed control efficiency were obtained with application of Pendimethalin @ 0.75 kg/ha as PE + HW at 45 DAS being at par with the treatment of HW and interculturing at 25 DAS + 45 DAS. Maximum net return and BCR were recorded with the application of Pendimethalin @ 0.75 kg/ha as PE + HW at 45 DAS over rest of the treatments.

Key words : Fennel, plant growth, weed index, weed control efficiency

India occupies the prime position in seed spices production and play important role in earning foreign exchange through the export of seed spices. Among the different *rabi* seed spices fennel (*Foeniculum vulgare* Mill.) commonly known as *Snafu* or *Variali* is one of the most major seed spices mainly grown in Gujarat, Rajsthan, Karnataka, Panjab and Haryana. Fennel is used for flavouring the soups, liquor, sauces, pastries, confectionary and bread roll. Initially fennel being slow growing seed spices is more prone to crop weed competitions. Extent of losses caused by weeds is the highest among all the loss causing agent like insects, pests and diseases. Therefore, crop should be kept weed free during initial stage for good crop establishment by employing suitable weed control method. Due to paucity of labours, manual weeding is very costly practice of weed control. Therefore, it is need of time to explore suitable alternate cost effective methods for weed control to keep the fennel crop free from weed at an initial stage of crop. Hence, the study on different methods of weed control in fennel was carried out for realizing high production and profitability from fennel crop.

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MATERIALS AND METHODS

A field experiment was carried out in *rabi* season of 2011-12 on loamy sand soil of Agronomy Instructional Farm, C. P. College of Agriculture, S. D. Agricultural University, Sardakrushinagar (Gujarat). The soil of the experiment field was light in texture having pH 7.4 and EC 0.11 dSm^{-1}, low in organic carbon (0.16 %), low in available nitrogen (151 kg/ha), medium in availble P_2O_5 (35 kg/ha) and high in available K_2O (288 kg/ha). The average rainfall ranged from 400-500 mm during July to September. The experiment comprised of twelve weed control methods viz; unweeded check, Oxyfluorfen @ 0.15 kg/ha as pre emergence (PE), Oxyfluorfen @ 0.30 kg/ha as PE, Oxyfluorfen @ 0.15 kg/ha as PE + HW at 45 days after sowing [DAS], Oxadiargyl @ 0.050 kg/ha as post emergence [POE] at 30 DAS, Oxadiargyl @ 0.075 kg /ha as POE at 30 DAS, Oxadiargyl @ 0.050 kg /ha as POE at 30 DAS + HW at 45 DAS, Pendimethalin @ 0.75 kg/ha as PE, Pendimethalin @ 1.0 kg/ha as PE, Pendimethalin @ 0.75 kg/ha as PE + HW at 45 DAS, HW and interculturing at 25 DAS and at 45 DAS and weed free were evaluated in randomized block design with four replications. The fennel crop (cv. Gujarat fennel-11) was sown at 45 cm row spacing during the *rabi* season of 2011-12 by drilling with seed rate of 5 kg/ha as a irrigated crop. The temperature ranged from 4.6 °C during January and 21.7 °C in the month of April during the growth period of the fennel crop. Full dose of phosphorus and half dose of nitrogen was applied as basal prior to sowing in the form of DAP and Urea. The remaining half dose of nitrogen was applied in the form of urea in two equal split coinciding with the irrigations. The required quantity of herbicides was applied by Knapsack sprayer with flat fan nozzle using 500 liters of water per hectare. Pre emergence herbicides was applied a day after sowing and before emergence of the weeds and crop seeds; and post emergence herbicides were applied as per treatments at 30 DAS. All the standard packages of practices were followed throughout the crop season. In weed free treatment, weeds were removed as and when required to keep it weed free throughout the growing season. After uprooting the weeds, the weeds were sun dried completely till reaches to the constant weight and final dry weight of weeds was recorded for each treatment and expressed as kg/ha. Net return and cost of cultivation were calculated based on the prevailing market prices for drawing conclusion.

RESULTS AND DISCUSSION

Weed parameters

The experimental plot was highly infested with different weeds. The major weed floras observed in the crop were *Chenopodium album* L., *Amaranthus. spinosus* L., *Cyperus rotundus* L., *Portulaca oleracea* L, *Boerhaavia diffusa* L., *Argemone mexicana* L., *Tribulus terrestris* L. and *Asphodelus tenuifolius* (L.) Cav.

Application of different herbicides significantly influenced the dry weed weight, WCE and weed index. Besides, weed free treatment, the lowest dry weed weight (360 kg/ha) was recorded with the application of pendimethalin @ 0.75 kg/ha as PE + HW at 45 DAS and lowest weed index (16.42%) was recorded by the treatment of HW and interculturing at 25 DAS + 45 DAS which was followed by the application of pendimethalin @ 0.75 kg /ha as PE + HW at 45 DAS (17.99 %). The highest WCE (83.19 %) were recorded by the application of pendimethalin @ 0.75 kg/ha as PE + HW at 45 DAS but it was found at par with the treatment of HW and interculturing at 25 DAS + 45 DAS (Table 3). The lowest dry weight of weeds and weed index may be due to less weed density resulting in lower dry weight of weeds. The results of Nagar *et al.*, (2009) also showed that the application of pendimethalin @ 1.0 kg/ha significantly reduced the total dry weight of weeds in coriander crop. They also revealed that the spraying of pendimethalin @ 1.0 kg/ha as pre emergence recorded higher weed control efficiency and lowest weed index as compared to oxyfluorfen @ 0.25 kg/ha and oxadiargyl @ 75 g/ha. Meena and Mehta (2009) in coriander observed that the lowest weed biomass and highest WCE at maturity were recorded with Oxadiargyl @ 75 g/ha followed by hand weeding.

Growth parameters

Different weed control treatments significantly influenced the plant height and number of branches per plant at different stages as well as at harvest. Besides weed free treatment, the highest plant height at 60, 90 and 120 DAS was recorded with the application of pendimethalin @ 0.75 kg/ha as PE + HW at 45 DAS. At maturity, the highest plant height was recorded by the treatment of HW and interculturing at 25 + 45 DAS but it was found at par with the application of pendimethalin @ 0.75 kg /ha as PE + HW at 45 DAS (Table 1). Weeds were effectively controlled under these treatments and hence there was no severe competition by weeds for moisture and nutrients leading to higher plant height. Plant height at 30 DAS was not influenced with different weed control treatments.

Besides weed free treatment, the highest number of branches per plant at 90 and 120 DAS was recorded with the application of pendimethalin @ 0.75 kg/ha as PE + HW at 45 DAS. At maturity, the highest number of branches per plant was recorded by the treatment of HW and interculturing at 25 DAS + 45 DAS but it was found at par with the application of pendimethalin @ 0.75 kg/ha as PE + HW at 45 DAS . The lowest number of branches per plant was recorded under unweeded check. The more number of branches per plant in weed free and with the application of pendimethalin @ 0.75 kg/ha as PE + HW at 45 DAS might be due to less number of broad, narrow and other weed species and lower green biomass of weeds which might be reduced the competition for moisture, nutrient and light resulting in higher growth of fennel crop. These results are in accordance with the findings of Chaudhary (1989). He reported that the application of pendimethalin @ 1.0 kg/ha significantly increased the plant height and number of branches per plant of cumin crop.

Table 1 Effect of weed management practices on growth attributes of fennel

Treatment	Plant height (cm)					Number of branches/plant		
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest	90 DAS	120 DAS	At harvest
T_1 : Unweeded check	8.3	20.2	56.7	68.0	78.0	0.5	9.2	10.3
T_2 : Oxyfluorfen @ 0.15 kg a.i. /ha as PE	8.4	23.9	73.9	90.3	107.5	2.4	10.7	11.3
T_3 : Oxyfluorfen @ 0.30 kg a.i. /ha as PE	9.6	24.2	81.7	102.2	109.5	5.4	11.4	12.3
T_4 : Oxyfluorfen @ 0.15 kg a.i./ha as PE + HW at 45 DAS	8.5	23.6	89.0	116.9	129.3	4.8	11.9	12.5
T_5 : Oxadiargyl @ 0.050 kg a.i. /ha as POE at 30 DAS	9.4	20.3	63.0	87.6	99.4	2.0	9.8	10.7
T_6 : Oxadiargyl @ 0.075 kg a.i. /ha as POE at 30 DAS	9.3	21.3	58.8	89.5	99.2	1.6	9.7	10.6
T_7 : Oxadiargyl @ 0.050 kg a.i. /ha as POE at 30 DAS + HW at 45DAS	9.1	21.3	77.5	95.2	108.7	4.6	10.7	11.5
T_8 : Pendimethalin @ 0.75 kg a.i. /ha as PE	9.3	25.7	87.4	111.4	122.8	4.9	11.6	12.7
T_9 : Pendimethalin @ 1.0 kg a.i. /ha as PE	9.4	25.2	92.2	113.5	126.9	5.2	12.0	12.6
T_{10}: Pendimethalin @ 0.75 kg a.i. /ha as PE + HW at 45 DAS	9.5	26.8	105.6	126.6	137.9	5.6	12.2	12.9
T_{11} : HW and interculturing at 25 DAS and 45 DAS	8.1	26.0	87.8	120.4	138.2	5.5	12.1	13.3
T_{12}: Weed free	11.0	29.1	102.3	125.8	142.1	5.7	13.1	13.9
S. Em. ±	0.73	1.56	4.50	6.22	7.76	0.19	0.43	0.49
C.D. at 5 %	NS	4.50	12.95	17.90	22.32	0.60	1.20	1.40
C.V. %	16.00	13.05	11.07	11.97	13.31	9.62	7.69	8.12

Table 2 Effect of weed management practices on yield attributes and yield of fennel

Treatment	Number of umbels/ plant			Umbellates/ umbel	Seeds/ Umbellate	Seed yield (kg/ha)	Stover yield (kg/ha)	1000 seed weight (g)	Harvest index (%)
	Primary	Secondary	Total						
T_1 : Unweeded check	5.0	8.0	13.0	16.7	17.5	616	2179	6.75	28.26
T_2 : Oxyfluorfen @ 0.15 kg a.i. /ha as PE	5.4	9.0	14.4	18.2	18.7	658	2368	6.98	27.78
T_3 : Oxyfluorfen @ 0.30 kg a.i. /ha as PE	5.5	9.5	15.0	21.3	20.3	716	2571	7.02	27.87
T_4 : Oxyfluorfen @ 0.15 kg a.i./ha as PE + HW at 45 DAS	5.6	10.4	16.0	21.5	21.3	722	2523	7.10	28.62
T_5 : Oxadiargyl @ 0.050 kg a.i. /ha as POE at 30 DAS	5.4	8.8	14.1	17.7	18.5	658	2400	6.85	27.42
T_6 : Oxadiargyl @ 0.075 kg a.i. /ha as POE at 30 DAS	5.2	8.3	13.4	17.0	18.0	642	2182	6.80	29.44
T_7 : Oxadiargyl @ 0.050 kg a.i. /ha as POE at 30 DAS + HW at 45DAS	5.4	10.0	15.4	18.5	19.1	704	2496	6.95	28.23
T_8 : Pendimethalin @ 0.75 kg a.i. /ha as PE	6.1	12.7	18.7	20.5	21.6	971	3145	7.08	30.88
T_9 : Pendimethalin @ 1.0 kg a.i. /ha as PE	6.2	12.7	18.8	22.5	22.5	1042	3339	7.15	31.20
T_{10}: Pendimethalin @ 0.75 kg a.i. /ha as PE + HW at 45 DAS	6.3	13.5	19.8	22.8	25.0	1099	3363	7.22	32.67
T_{11}: HW and interculturing at 25 DAS and 45 DAS	6.5	13.7	20.2	22.7	24.8	1120	3512	7.21	31.90
T_{12}: Weed free	6.8	16.2	23.0	24.0	26.2	1340	4164	7.35	32.18
S. Em. ±	0.24	0.47	0.84	1.07	0.99	39	186	0.11	2.68
C.D. at 5 %	0.7	1.4	2.4	3.1	2.9	112	536	0.31	NS
C.V. %	8.31	8.51	10.0	10.55	9.38	9.09	13.06	3.09	18.03

Table 3 Effect of weed management practices on weed indices and economics of fennel

Treatment	Weed weight (kg/ha)		Weed control efficiency (%)	Weed index (%)	Gross realization (₹/ha)	Total expenditure (₹/ha)	Net realization (₹/ha)	BCR
	Green	Dry						
T_1 : Unweeded check (4519)*	67.21 (2141)	46.28	-	54.05	43102	21073	22029	1.05
T_2 : Oxyfluorfen @ 0.15 kg a.i. /ha as PE (3689)	60.63 (1710)	41.36	20.12	50.91	46051	21692	24359	1.12
T_3 : Oxyfluorfen @ 0.30 kg a.i. /ha as PE (3071)	55.33 (1651)	40.63	22.86	46.53	50150	22011	28139	1.28
T_4 : Oxyfluorfen @ 0.15 kg a.i./ha as PE + HW at 45 DAS	53. 17 (2840)	35.46 (1257)	41.30	46.10	50556	22892	27664	1.21
T_5 : Oxadiargyl @ 0.050 kg a.i. /ha as POE at 30 DAS	59.53 (3550)	43.02 (1850)	13.51	50.89	46067	21446	24621	1.15
T_6 : Oxadiargyl @ 0.075 kg a.i. /ha as POE at 30 DAS	62.22 (3872)	42.44 (1801)	15.93	52.06	44965	21483	23482	1.09
T_7 : Oxadiargyl @ 0.050 kg a.i. /ha as POE at 30 DAS + HW at 45DAS	48.75 (2384)	35.79 (1280)	40.08	47.43	49314	22646	26668	1.18
T_8 : Pendimethalin @ 0.75 kg a.i. /ha as PE (2537)	49.88 (750)	27.40	64.97	27.53	67975	22181	45794	2.06
T_9 : Pendimethalin @ 1.0 kg a.i. /ha as PE (2332)	48.12 (671)	25.92	68.63	22.26	72925	22446	50479	2.25
T_{10} : Pendimethalin @ 0.75 kg a.i. /ha as PE + HW at 45 DAS	41.12 (1751)	18.98 (360)	83.19	17.99	76929	23383	53546	2.29
T_{11} : HW and interculturing at 25 DAS and 45 DAS	44.78 (2007)	22.12 (489)	76.73	16.42	78403	24073	54330	2.26
T_{12} : Weed free (0.00)	0.71 (0.00)	0.71	100.00	-	93803	28873	64930	2.25
S. Em. ±	1.88	0.80	2.95	2.47	-	-	-	-
C.D. at 5 %	5.4	2.3	8.95	7.11	-	-	-	-
C.V. %	7.63	5.03	12.95	13.73	-	-	-	-

Yield attributes and yield

Yield attributes as well as seed and straw yield were significantly influenced by various weed control practices. Results revealed that beside weed free treatment, application of pendimethalin @ 0.75 kg / ha as PE + HW at 45 DAS being at par with HW and interculturing at 25 DAS + 45 DAS recorded significantly higher yield attributes like; number of umbels per plant (20.2), number of umbellates per umbel (22.8), seeds per umbellate (25.0), 1000 seed weight (7.22 g), seed (1120 kg/ha) and straw (3512 kg/ha) yields (Table 2). Increase in yield attributes with pendimethalin @ 0.75 kg/ha as PE + HW at 45 DAS might be due to effective control of weeds resulting in lesser competition of weeds which might have ultimately resulted in better utilization of nutrients and moisture available in the soil by the fennel crop, which reflects in term of increased yield attributes and yield of fennel. These finding are in according with the findings of Sagarka *et al.,* (2005). They reported that the application of pendimethalin @ 0.90 kg/ha + one hand weeding significantly increased the seed and stover yields of coriander as compared to other treatments. Chaudhary (2000) also reported that the application of pendimethalin @ 1.0 kg/ha + one hand weeding increased harvest index and seed yield of fennel crop. The results are also in accordance with the results of Parihar and Singh (1994) in cumin crop and Nagar et al., (2009) in coriander crop.

Economics

Application of weed control treatments significantly influenced the gross return, net return and benefit : cost ratio in fennel. Highest net return (₹ 54330/ha) was recorded by the treatment of HW and interculturing at 25 DAS + 45 DAS and was followed by the application of pendimethalin @ 0.75 kg/ha as PE + HW at 45 DAS (53546 /ha). In case of B : C ratio, the highest B : C ratio of 2.29 was recorded by the application of pendimethalin @ 0.75 kg/ha as PE + HW at 45 DAS (Table 3).

Thus, it is concluded that the maximum seed yield, net realization and effective control of weeds can be achieved by keeping the fennel crop weed free through out the growing period or by hand weeding and interculturing at 25 DAS + 45 DAS where there is no shortage of labours. However, under the paucity of labours, higher seed yield and net returns of *rabi* fennel can be secured by the application pendimethalin either @ 0.75 kg/ha as PE along with HW at 45 DAS or pendimethalin @ 1.0 kg/ha as PE.

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Accelerate storage validation for the production of thermally processed bottle gourd *(L. siceraria)* blended juice

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ABSTRACT

Experiments were carried out during year 2014 at FPTBE College, AAU, Anand to study the accelerated storage validation to produce thermally processed blended juice. Accelerated storage conditions were at 37°C for 10 days and 55°C for 7 days as per food safety and standards act 2006, rules and regulations (FSSRs), 2011. The total soluble solids of blended juice samples was above 5 ^{0}brix and found no significant (P>0.05) effect after the storages, though it was most stable. The significant decreased in ascorbic acid was noticed higher after 7 days storage at 55 ^{0}C and the maximum loss was 11.31 %. The total plate counts (cfu/ml) were found below food safety standards rules and decreased remarkably during storages. The yeasts and moulds count (cfu/ml) in the blended juice were increased significantly (P<0.05) after 37°C for 10 days storage and showed inverse relationship with the 55°C for 7 days storage. As per standards, the product was stable and microbiologically safe, hence; validated for commercial production as it satisfies require accelerated storage conditions.

Key words : Bottle gourd, blended juice, accelerated storage, total plate counts

Bottle gourd (*Langenaria siceraria*), a vigorous annual climbing vine with large leaves belongs to *Cucurbitaceae* family and known as Calabash, Doodhi, and Lauki in different parts of India (Deore *et al.*, 2009). India, Sri Lanka, South Africa, Indonesia and Malaysia are the major bottle gourd producing countries in the world. The bottle gourd is also known in other places as White flowered gourd, Trumpet gourd, Calebassier, Courage bouteille (French) Cojombro, Guiro amargo (Spanish), Upo, Talayag, Gucuzzi, Zucca melon (Philippines), Mokwa, Oo Lo Kwa (China) (Axtell and Fairman, 1992). Bottle gourd fruit contains almost 96% moisture but is rich in vitamins, minerals, antioxidants and dietary fibers. A 100 g of edible portion of the bottle gourd contains 12.0 mg ascorbic acid, 87.0 mg potassium, 12.0 mg calcium, 37.0 mg phosphorus and 0.3 mg niacin (Rumeza *et al.*, 2006; Sawate *et al.*, 2009). Bottle gourd contents 1.6% choline on a dry weight basis and is a precursor to acetylcholine, a chemical used to transfer nerve impulses (Thomas, 2008).

Bottle gourd has long been an important component of indigenous herbal medicine, particularly in Asia (Robinson and Decker-Walters, 2004) and traditionally used as a nutritive agent having cardioprotective, cardiotonic, general tonic, diuretic, aphrodisiac, antidote to certain poisons, alternative purgative, and cooling effects (Deshpande *et al.*, 2008). Bottle gourd plant is seasonal and hence supply of bottle gourd fruit is not uniform through the year. The bottle gourd fruit having higher edible index (94.17 %) and lower waste index (5.83 %) which proves its importance for processing (Sawate *et al.*, 2009). It is still underutilized fruit in spite of being one of the cheapest source of nutrients and potential source of natural antioxidants and hence, steps should be taken to preserve this perishable but nutritionally important fruit by extending the shelf-life in the processed form. Production of superior quality juice is one way to process the bottle gourd but bottle gourd juice in its pure form is difficult to preserve because of its lower acidity (0.17 %) and high concentration of spore forming bacteria (Kothadia, 2010). Acidification may convert low acid juice to an acidic juice and allow the use of milder thermal process conditions (James and Shen, 2011). To prepare such natural form of low acid juices, Bottle gourd juice can be blended with other acidic fruit juices namely Aonla *(Emblica officinalis Gaertn.)* and Lemon *(Citrus x limon)* with spice extracts like Ginger *(Zingiber officinale)*.

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Production of such juice is mostly done manually in the household or at cottage level, which is less hygienic with high chances of degradation within few hours. Different processing conditions are used with little knowledge of the effect of the treatment conditions on the physiochemical and microbiological quality on the final stored product. Therefore, this research work was conducted to determine the effect of accelerated storage on quality of thermally processed bottle gourd blended juice and its validation for production at commercial level.

MATERIALS AND METHODS

Pre-treatments and juicing

Tender bottle gourd fruits (cv. ABG-1) and fresh aonla fruits (cv. Anand-2) were procured from the Horticultural Farm, Anand Agricultural University, Anand. Matured lemon and ginger were procured from the local vegetable market, Anand, India. Procured raw fruits were thoroughly washed in the running tap water to remove surface adhering extraneous material, insecticides, pesticides, contaminations and the other microbial load. The bottle gourds were sliced and blanched to inactivate peroxidase enzymes prior to juicing (Gajera *et al.*, 2014). Aonla fruits were also blanched in boiling water before juicing. The juice from the blanched bottle gourd slices and aonla fruits was extracted using the same centrifugal juicer (Rama udyog, Jaipur, India) and strained through muslin cloth. For juice extraction from lemon, fruits were cut into two halves with the help of stainless steel knives and juice was extracted by squeezing manually and strained through muslin cloth. For juice extraction from ginger, cut slices were fed into domestic mixer cum grinder and strained through muslin cloth.

Product development

All the four juices prepared as above were blended using central composite design with response surface methodology. Design expert® 8.0.7.1 (Statease Inc., Minneapolis, USA) software; based on numerical technique was used for optimization of the blended juice. Optimized blended juice as obtained was hot filled in pre-sterilized 200 ml glass bottles and crown corked using hand operated sealing machine. Hot filled crown corked bottles were immediately subjected to thermal processing in hot water. The temperature and time of processing were over 80, 85, 90 and 95°C for 5, 10, 15, 20, 25 and 30 min. The process was carried out at atmospheric pressure by immersing bottles into the autoclave (Nova Instruments Pvt. Ltd., Ahmedabad).

Accelerated storage

Thermally processed at above temperatures and time, cooled bottles of blended juice was subjected for accelerated storage at 37 °C for 10 days and 55 °C for 7 days in incubator (Khera Instruments Pvt. Ltd., New Delhi) as per food safety standards regulations as described by Nijhawan (2012).

Proximate analysis

The total soluble solids was measured using pocket hand refractometer-PAL-1(ERMA, Japan) having measuring range 0-53 °Brix. The ascorbic acid content of blended juice was determined by visual titration method using 2, 6-dichlorophenol-indophenol while total plate counts, yeast and mold counts and coli form counts were carried out using standard procedures as described by Ranganna (2004). For the analysis, ascorbic acid standard (99%) were procured from SD Fine Chemicals Mumbai, India, and plate count agar, PDA and VRBA were procured from Hi-Media Laboratories Pvt. Ltd., Mumbai. For all assays, de-ionized distilled water was used.

Statistical analysis

The data obtained (mean ± standard deviation) after the accelerated storage experiments were analyzed by BASIC statistical software using 2-factors, 4- 6 levels CRD and results were analyzed by analysis of variance using $p < 0.05$.

RESULTS AND DISCUSSION

Effect on TSS

The TSS observed was in the range 5.37 to 5.23 °Brix across the treatments after accelerated storages with maximum variation 0.14 °Brix (Fig. 1). The TSS was significantly affected over the processed temperature (T) at 5% level of probability. The TSS of blended juice was most stable with increased over processed time (PT), though it was not significant. However, the interaction of both the parameters was found to be non-significant after the storage (Table 1). Non significant increase in total soluble solids in blended juice after accelerated storages was might be due to hydrolysis of polysaccharides into monosaccharide and oligosaccharides. The result was supported by Majumdar *et al.*, (2009); Jan *and Masih,* (2012) and Kausar *et al.*, (2012).

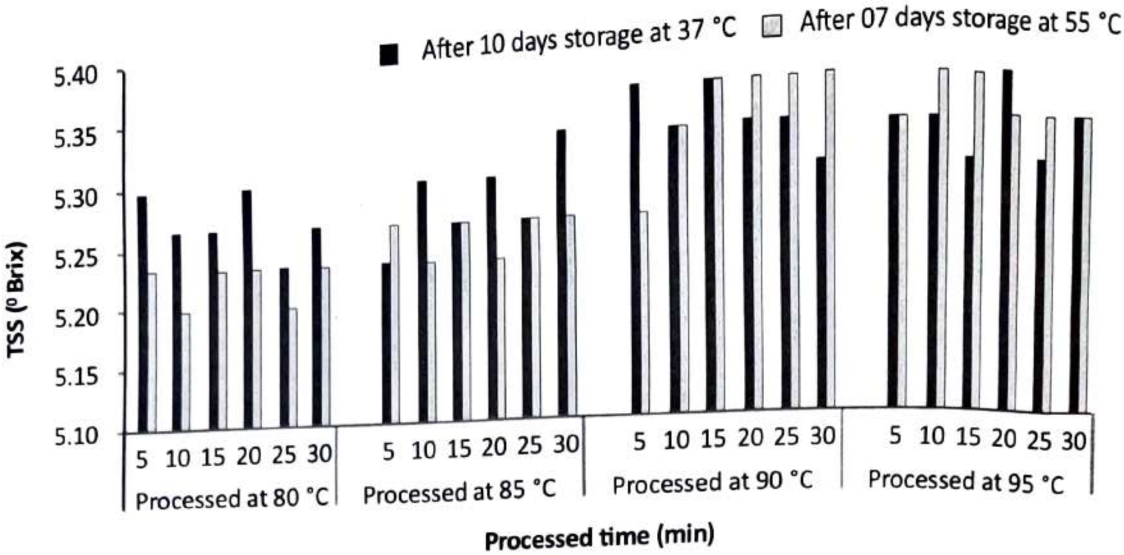

Fig. 1 Effect on total soluble solid of thermally processed blended juice after accelerated storage

Table 1 Statistically mean analyzed data showing the effect of thermally processed blended juice at varying processed time and temperatures on physicochemical and microbiological quality after accelerated storage

Treatment	TSS (°Brix)		Ascorbic acid (mg/100 ml)		Total plate count (cfu/ml)		Yeast & mould count (cfu/ml)	
	@	#	@	#	@	#	@	#
Processed time (PT)								
PT_1	5.3083	5.2750	34.0717	32.7967	18.2500	16.1667	2.5833	0.8333
PT_2	5.3083	5.2833	33.6642	31.8458	14.4167	12.9167	1.4167	0.5833
PT_3	5.3000	5.3083	32.4208	31.0775	7.6667	7.8333	0.9167	0.1667
PT_4	5.3250	5.2917	31.7742	30.3325	6.0000	5.1667	0.2500	0.0833
PT_5	5.2833	5.2917	30.3092	29.0683	3.5000	3.2500	0.0833	0.0000
PT_6	5.3083	5.3000	29.2867	28.1517	2.4167	2.0833	0.0000	0.0000
SEm ±	0.014	0.017	0.224	0.204	0.607	0.515	0.223	0.090
CD (P=0.05)	NS	NS	0.636	0.579	1.725	1.463	0.634	0.256
Processed temperature (T)								
T_1	5.2722	5.2222	35.1444	33.6200	15.7778	13.7222	3.5000	1.1111
T_2	5.2833	5.2556	33.5983	31.9883	10.3333	9.6667	0.0000	0.0000
T_3	5.3389	5.3444	30.4956	29.2978	5.5000	5.2222	0.0000	0.0000
T_4	5.3278	5.3444	28.4461	27.2756	3.2222	3.0000	0.0000	0.0000
SEm ±	0.011	0.014	0.183	0.166	0.495	0.420	0.182	0.073
CD (P=0.05)	0.033	0.039	0.519	0.473	1.408	2.013	0.518	0.209
Interaction (PT x T)								
SEm ±	0.028	0.034	0.447	0.407	1.213	1.735	0.446	0.180
CD (P=0.05)	NS	NS	1.272	1.158	3.449	1.195	1.268	0.512
CV %	0.92	1.11	2.43	2.31	24.13	22.57	88.32	112.25

PT_1=5 min, PT_2=10 min, PT_3=15 min, PT_4=20 min, PT_5=25 min and PT_6=30 min
T_1=80°C, T_2=85°C, T_3=90°C and T_4=95°C

@ Values after storage at 37°C for 10 days (mean ± std. deviation)
# Values after storage at 55°C for 7 days (mean ± std. deviation)

Effect on ascorbic acid

The minimum ascorbic acid content of thermally processed blended juice was decreased to 6.44 % and the maximum 11.31 % after accelerated storage at 37 °C for 10 days and 55 °C for 7 days, respectively (Fig. 2). The significant ($P<0.05$) decreased in ascorbic acid was noticed higher at 55 °C temperature for 7 days. Processed time (PT) and temperature (T) increased indicated they were not governing independent (Table 1). Result confirmed that the low temperature long time storage of thermally processed blended juice exhibited a higher protective role of ascorbic acid than high temperature short time storage.

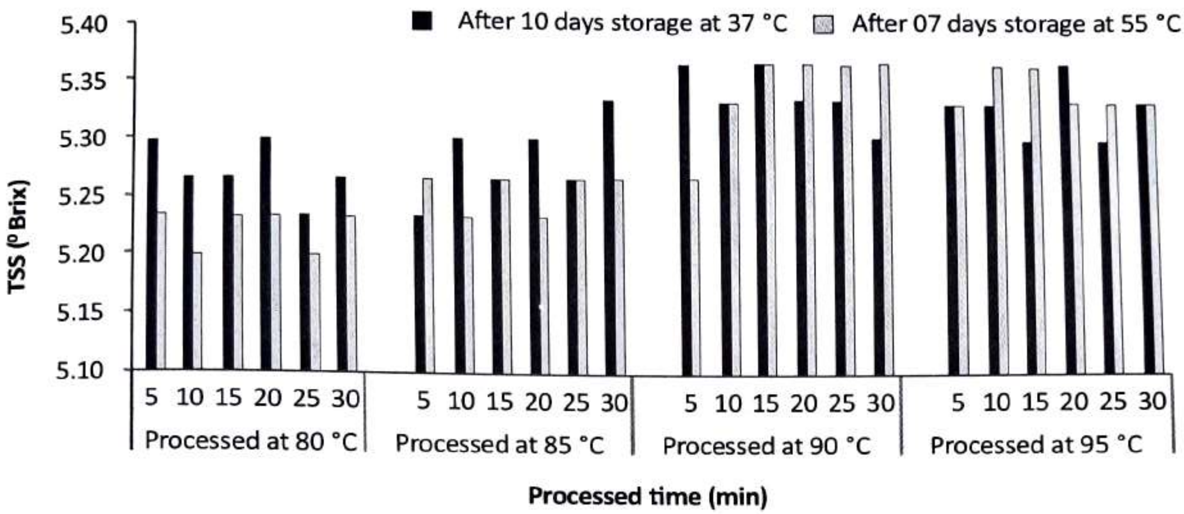

Fig. 2 Effect on ascorbic acid content of thermally processed blended juice after accelerated storage

Effect on total plate counts

maximum total plate counts in thermally processed blended juice was 31 and 28 cfu/ml after 37 °C for 10 days and 55 °C for 7 days, respectively (Fig. 3). The minimum total plate counts was nil after 37 °C for 10 days and 55 °C for 7 days in 30 min for 95 °C thermally processed blended juice. The total plate counts were decreased remarkably and had significant effect ($P<0.05$) after the storages (Table 1). However, decreased was higher in 55 °C for 7 days accelerated storage as compared to 37 °C for 10 days. This might be due to the inhibitory effect of thermophilic temperature of storage rather than masophilic towards the total plate counts of thermally processed acidic blended juice. The total plate counts were not grew which might be due to the acidic environment of the blended juice and stable TSS. The finding was in conformity with the results reported by Derossi *et al.*, (2011).

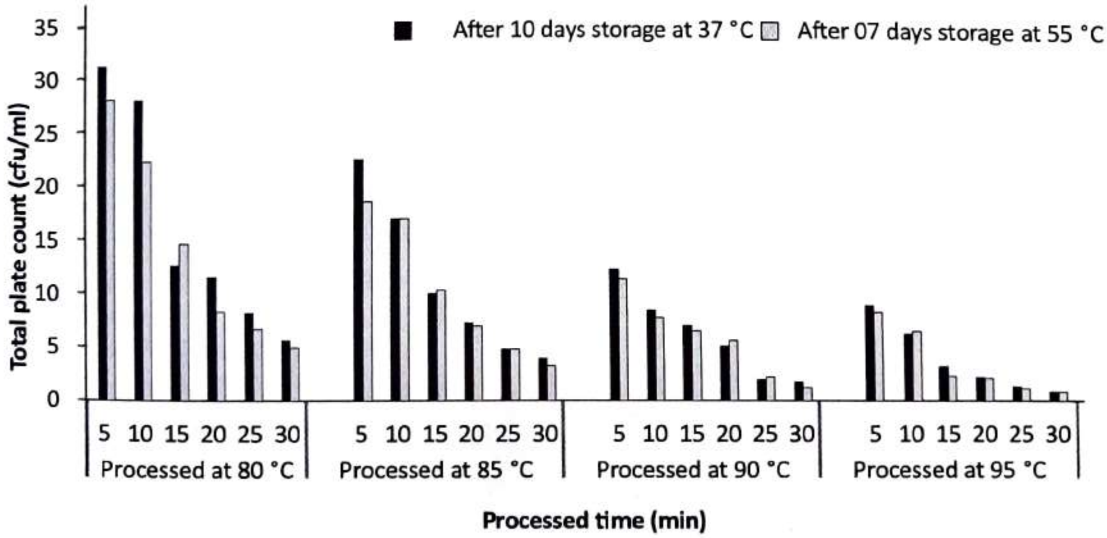

Fig. 3 Effect on total plate counts of thermally processed blended juice after accelerated storage

Effect on yeast and mould counts

The maximum yeast and mould counts were 10 and 3 cfu/ml, respectively after 37 °C for 10 days and 55 °C for 7 days accelerated storage in 5 min for 80 °C thermally processed blended juice (Fig. 4). The yeast and mould counts increased remarkably and significantly (P<0.05) after both the storages (Table 1). However, yeast and mould counts were absent after accelerated storage in thermally processed blended juice at 25 min for 80 °C and 5 to 30 min for 85 to 95°C. Result revealed that the yeasts and moulds can tolerate masophilic temperature rather than thermophilic temperature in the lower acidic environment of blended juice. The coli form counts (cfu/ml) was nil after both the storages.

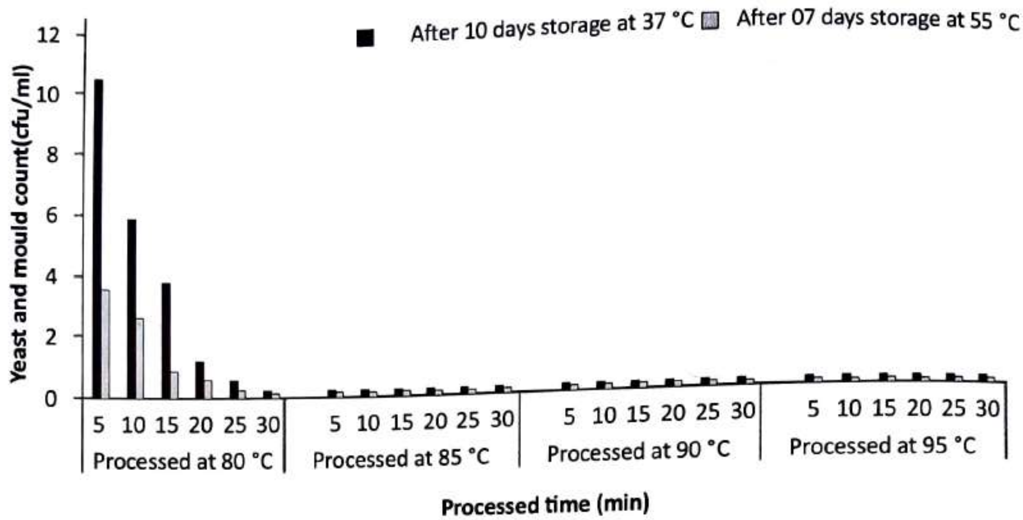

Fig. 4 Effect on yeast and mould counts of thermally processed blended juice after accelerated storage

CONCLUSION

After the accelerated storage, thermally processed blended juice TSS was above 5.0 °Brix and remained most stable. The total plate counts also were not more than 50cfu/ml after the storages as per food safety and standards act 2006, rules and regulations (FSSRs), 2011. The minimum and the maximum loss of ascorbic acid in blended juice was 6.44 and 11.31 % after accelerated storage at 37 °C for 10 and 55 °C for 7 days, respectively. The product was validated for commercial production, as it was stable and microbiologically safe after accelerated storages.

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Profitability of arecanut cultivation in the Kasaragod district in Kerala

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ABSTRACT

A unique feature of Kerala's agriculture in general and Kasaragod district in particular is that the cropping pattern has shifted in favour of commercial crops. In this shift, plantation crops increased considerably. Arecanut is an important commercial crop in the Kasaragod district of Kerala. During the past three decades, the arecanut cultivation underwent significant increase in area and production due to area effect and the yield effect. The input wise distribution of cost of arecanut by size of farm did not indicate any specific relation between the total cost of cultivation and the size of farm. Yield per hectare of arecanut indicated inverse relation with the size of farm. Estimating costs and returns of arecanut cultivation in Kasaragod in terms of PBP, IRR, NPV and BCR revealed that arecanut cultivation is profitable in the district. The study also revealed that profitability of arecanut is inversely related to the size of arecanut garden

Key words : Kasaragod, arecanut cultivation, cost of cultivation, profitability

Arecanut is used by all sections of people as masticator either alone or in combination with betel leaves, lime and tobacco. It is an essential requisite for several religious and social ceremonies. In olden days it was used as a human and veterinary medicine (Bhalerao and Singh, 1985). With the development of modern medicine, its medicinal value steadily began to wane. The arecanut palm grows in different climatic and soil conditions and is grown in India, Bangladesh, Srilanka, Malaysia, Indonesia, Philippines and Myanmar (Jose and Jayasekhar, 2008). In India, among the arecanut growing states, Kerala, Karnataka and Assam account for 95 percent of total area and 90 percent of total production (Anonymous, 2014). In Kerala, arecanut is cultivated in all districts. The proportion of area under arecanut in the state is very high when compared with other states. In terms of income, arecanut occupies an important place in the economy of Kerala and it is predominantly a small farmer's crop (Karunakaran, 2015).

Kasaragod District was organised on 24th May 1984 and is the northernmost district of the State of Kerala. The land use pattern shows that, in the district arecanut is the major crop next to coconut and rubber, accounting about ten percentage of the total cropped area (Karunakaran, 2014). In the district, arecanut is mainly a small farmer's crop and more than 75 percentages of the holdings are of less than two hectares in size. Any change in its cultivation either in terms of area, production or productivity would seriously affect the weaker sections of the agriculture population. The present study is therefore, an attempt to analyse the profitability of arecanut cultivation in the Kasaragod district against the background of the agricultural sector of Kerala.

MATERIALS AND METHODS

The study used both primary and secondary data. Primary data was collected from seventy two arecanut growers of the Kasaragod district. The major source of secondary data are various published reports of the Department of Economics and statistics, Thiruvananthapuram, State planning Board, Thiruvananthapuram, Directorate of Cocoa, Arecanut and spices Development, Kozhikode and Directorate of Economics and statistics, Government of India.

The time element in the calculation of cost and returns has been taken care of seriously (Singh, *et.al*, 1982) for evaluating the profitability of arecanut gardens with the

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help of the four major techniques widely used in the project evaluation. These four techniques are given below:

Pay Back Period (PBP)

The PBP is the number of years an investment project taken to recover costs from its returns. The PBP equals t^*, where t^* is the lowest value of 't' for which the following inequality holds:

$$\sum_{t=1}^{t*} Ct < \sum_{t=1}^{t*} Rt$$

Where,

Rt = Return in Period t

Ct = Cost in Period t.

Net Present Value (NPV)

The NPV on investment is the discounted value of all cash inflows, net of all cash outflows of the project during its life time. It can be computed as:

$$NPV = \sum_{t=1}^{T} \left(\frac{Rt - Ct}{(1+i)t}\right)$$

Where,

i = discounted rate

T = number of years.

Internal Rate of Return (IRR)

The IRR is that discount rate at which the NPV is zero. The equation for its calculation is

$$\sum_{t=1}^{T} \left(\frac{Rt - Ct}{(1+r)t}\right)$$

BENEFIT COST RATIO (BCR)

The BCR of an investment is the ratio of the discounted value of all cash inflows to the discounted value of all outflows during the life of the project. It can be computed as

$$BCR = \frac{\sum_{t=1}^{T} \frac{Rt}{(1+i)t}}{\sum_{t=1}^{T} \frac{Ct}{(1+i)t}}$$

RESULTS AND DISCUSSION

In Kerala, the area and production of arecanut is spread in almost all districts. Table 1 shows the area under cultivation of arecanut in Kasaragod district. The percentage of arecanut area increased considerably in the district.

Table 1 Changes in the area under Arecanut crop in Kasaragod district (1985-86 to 2013-14)

Sr. No.	Year	Area (in hectare)	Percentage increase
1	1985-86	8907	-
2	1990-91	12269	38
3	1995-96	12710	43
4	2000-01	13515	52
5	2005-06	17622	98
6	2006-07	14910	67
7	2007-08	15060	69
8	2008-09	14927	68
9	2009-10	15256	71
10	2010-11	18039	103
11	2011-12	19552	120
12	2012-13	18937	113
13	2013-14	19488	119

Source : Computed from (i) Statistics for planning (various issues), Department of Economics and Statistics, Govt. of Kerala, Thiruvananthapuram. (ii) Economic Review (various issues), State Planning Board, Govt. of Kerala, Thiruvananthapuram.

In 1960-61, the area under arecanut was 55 thousand hectare. In all the decades except 1970's, Kerala experienced significant increase in the area under arecanut cultivation (Karunakaran, 2013). During the last five decades, many of the northern districts and central districts observed percentage increase in the area and all the southern districts showed decrease in the area under arecanut cultivation.

In Kasaragod, coconut, arecanut, rubber and banana observed increase in the proportion of area. Area under rice, pepper, cashewnut, tapioca, cardamom and ginger experienced declining trend. One important feature of the cropping pattern of Kasaragod district is the high proportion and continuous increase of arecanut area in the total cropped area (Table 2).

Table 2 Cropping Pattern change in the Kasaragod District in Kerala

Sr. No.	Crops	1985-86	1990-91	1995-96	2000-01	2005-06	2013-14
1	Rice	3	4	5	5	6	6
2	Coconut	1	1	1	1	1	1
3	Arecanut	6	5	4	4	4	3
4	Rubber	4	3	3	2	2	2
5	Pepper	5	6	6	6	5	5
6	Cashewnut	2	2	2	3	3	4
7	Tapioca	7	8	8	8	8	8
8	Ginger	9	9	9	9	9	9
9	Banana	8	7	7	7	7	7

Figures shows rank of each crop in the Total Cropped Area

Source : Computed from (i) Statistics for planning (various issues), Department of Economics and Statistics, Govt. of Kerala, Thiruvananthapuram. (ii) Economic Review (various issues), State Planning Board, Govt. of Kerala, Thiruvananthapuram.

Arecanut cultivation is the chief economic activity of the district. It is a main source of income and employment. Therefore its further development is a real necessity. As long as cultivation is in the private sector, commercial farmer will continue the cultivation only if it is a gainful activity (Duggappa, 2013). The profit or loss of cultivation of a crop is the difference between the cost of various inputs used and the value of main product and the by product obtained from it (Gopal Naik and Arora, 1986). Therefore, an analysis of the costs and returns is very relevant to measure the profitability of arecanut cultivation.

Input-wise maintenance cost of arecanut

The input-wise maintenance cost of arecanut is estimated under the three different concepts of cost and is presented in Table 3. The important items of Cost A are seed/seedlings, hired human labour, farm yard manure, chemical fertilizers, irrigation, depreciation, plant protection, interest on working capital and other expenses. Cost B includes Cost A, rental value and interest on fixed capital. Cost C is the totality of Cost B and family labour charges.

The estimated cost of arecanut cultivation under various cost concepts given in Table 3 indicated that cost A, B and C exhibited positive relation with the size of arecanut farm. The proportion of total costs on hired human labour, farm yard manure, irrigation chemical fertilizers, plant protection, interest on working capital and other expenses indicate positive relation with the size of farm; whereas proportion on total cost on seed/seedlings, depreciation, rental value, interest on fixed capital and family labour charges exhibited negative relationship with the size of farm. Among the small farmers, hired human labour charges accounted for the highest share of the total cost, followed by farm yard manure, rental value, family labour charges, irrigation and interest on fixed capital. In the case of medium farmers also hired human labour charges accounted for the highest share of the total cost followed by farm yard manure, rental value, irrigation, family labour charges and interest on working capital. The large farmer's hired human labour charges accounted for the highest share of the total cost, followed by farm yard manure, rental value, irrigation costs, interest on working capital and interest on fixed capital.

Average yield of arecanut

The data presented in Table 4 indicated that size of farm is negatively related to yield per hectare. It is

Table 3 Input-wise proportion of maintenance cost of Arecanut in the Kasaragod district

Sr. No.	Particulars	Size of arecanut farm		
		Small	Medium	Large
1	Seed/seedlings	3.56	3.31	2.93
2	Hired Human Labour	39.65	40.15	41.35
3	Farm yard manure	13.68	14.03	14.84
4	Chemical Fertilizers	3.73	3.61	3.49
5	Irrigation	5.94	6.32	6.32
6	Depreciation	3.00	2.52	2.10
7	Plant Protection	3.67	4.04	3.92
8	Interest On Working Capital	5.58	5.79	6.06
9	Other Expenses	2.92	3.55	4.35
	Cost A	81.74	83.33	85.34
10	Rental Value	4.36	4.19	4.00
11	Interest On Fixed Capital	5.94	5.44	5.37
	Cost B	92.04	92.96	94.72
12	Family Labour Charges	7.96	7.04	5.28
	Cost C	100.00	100.00	100.00

Figures indicate percentage to total cost.

Source: Primary Data.

estimated that the average yield of arecanut per hectare is 17.50 quintals for small farm, 16.80 quintals for medium farm and 15.25 quintals for large farm.

Profitability of arecanut cultivation

Since the gestation period for arecanut is much longer than that for other crops and its economic life is about 50 years, the time element in the calculation of cost and return was worked out for evaluating the profitability of arecanut garden. This is by discounting of costs and returns. The age wise data on costs and returns were also worked out for computing the various measures of profitability. The net present value (NPV) and benefit cost ratio (BCR) are functions of discount rate and are negatively related to discount rate. The discount rate used in the study is equal to the opportunity cost of capital and since the opportunity cost could vary from 8 to 15 percent, these measures were calculated separately for two discount rates, *viz.*, 12 and 14 per cent.

Table 4 Yield per Hectare of Arecanut in the Kasaragod district

Sr. No.	Size of arecanut farm	Yield (in Quintals)
1	Small	17.50
2	Medium	16.80
3	Large	15.25

Source: Primary Data.

The four measures of profitability, *viz.*, payback period (PBP), net present value (NPV), internal rate of return (IRR) and benefit cost ratio (BCR) were calculated and the result is given in Table 5.

The payback period obtained (13 years) is less than the maximum PBP (14 to 15 years) desired by the farmers in the district. Hence, according to the criteria of PBP, arecanut cultivation is profitable in the district. Results of Net Present Values (NPV) at 12 per cent and 14 per cent were positive and quiet high also indicates the profitability of arecanut cultivation. The Internal Rate of Return ranged from 33.40 per cent for large farmers to 33.70 per cent for medium farmers. It was much greater than the cost of borrowing capital, which ranged from 10 to 15 per cent, for borrowing from financial institutions in Kerala shows that arecanut cultivation is profitable. The benefit cost ratio at 12 percentage of discount rate ranged from 1.48 percent in large farmers to 1.96 per cent in medium farmers. Even at a higher rate of discount of 14 per cent, the BCR ranged from 1.42 per cent in large farmers to 1.52 per cent in medium farmers. In all the size groups it was greater than unity. Hence, according to the criterion of BCR also arecanut cultivation is profitable.

Table 5 Profitability of Arecanut crop in the Kasaragod District

Sr. No.	Particulars	Size of arecanut farm		
		Small	Medium	Large
1	PBP (Years)	12.80 (I)	13.30 (II)	13.60 (III)
2	IRR (%)	33.50 (II)	33.70 (I)	33.40 (III)
3	NPV (Rs)			
4	At 12 %	38204 (II)	47758 (I)	29992 (III)
5	At 14 %	21476 (II)	25696 (I)	19622 (III)
6	BCR			
7	At 12 %	1.88 (II)	1.96 (I)	1.48 (III)
8	At 14 %	1.50 (II)	1.52 (I)	1.42 (III)

Figures in bracket indicate rank.

CONCLUSION

The agricultural economy of the district has been showing signs of stagnation or even decline in a few of its most important sectors. One important feature of the agriculture sector of the district is that of change in cropping pattern in favour of commercial crops. In this, plantation crops increased considerably.

Arecanut cultivation is one of the main economic activities of the district and is an important source of income and employment to the people. Therefore, an analysis of the costs and returns of this crop is a real necessity so as to measure the profitability. The input wise distribution of cost of arecanut by size of farm did not indicate any specific relation between the total cost of cultivation and the size of farm. Yield per hectare of arecanut indicated inverse relation with the size of farm. Estimating costs and returns of arecanut cultivation in the district found that arecanut cultivation is profitable. It is also revealed that profitability of arecanut is inversely related to the size of farm. This clearly reveals the implementation of proper measures and policy decisions on the part of the government for the effective development of arecanut crop in the district.

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Scraped Surface Heat Exchanger for Dairy Industry- A Review

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ABSTRACT

Scraped surface heat exchanger (SSHE) is more suitable for heat transfer for viscous and heat sensitive products in dairy industry. It is easier to control time, temperature and pressure in a SSHE than in a kettle. The use of SSHE for the manufacture traditional Indian Dairy Product helps in reducing man power and improving quality as well as shelf life of the product. SSHE of various design are being used for manufacture of TIDP as well as for western product such as icecream, cheese etc. The choice and design of heat exchanger depends on Flow rate of both streams, Heat sensitivity and corrosivity of the fluids, Terminal temperatures, Properties of both streams, Operating pressure and temperature, Pressure drop, Fouling tendencies, Type and phase of fluids, Material of construction, Heat recovery, Flow arrangement etc. The scraping action of the blades rotating within the heat transfer tube continuously removes the product film from the heat exchanger surface and prevents burning-on, scaling or crystal build up on the wall. This type of heat exchangers can be used for batch or continuous heating or cooling of products. The major advantages of SSHE include short residence time in heated zone so heat sensitive product can be conveniently processed, high heat transfer coefficient, narrow residence time distribution, wide viscosity range, minimum surface fouling. SSHE basically consists of a cylindrical rotating shaft within a concentric hollow stationary cylinder so as to form an annular region along which the process fluid is pumped. In a typical SSHE there are usually two or four blades located periodically around the rotor throughout the product tube, though sometimes they are axially staggered in order to improve mixing. Liquid-full operation and thin-film operations are very commonly used in SSHE. Thermal and electrical energy are required in operations of SSHE. The electrical energy required for driving the rotor is very small as compared to the thermal energy required to evaporate the water. Structural design of SSHE includes the calculation of size, shape and strength of each component of the SSHE to handle the product efficiently, material of construction require to meet the requirements from the view point of food hygiene and sensory attributes of the product, the finish of the surface and the mechanical power to run the unit successfully and efficiently. More advanced designs of SSHE are available in the market for various applications. There is a good scope for SSHE to prepare indigenous milk products *viz.*, basundi, peda, khoa, halava or in general any khoa based sweets on commercial basis.

Key words : Scrape surface, dairy, heat exchanger.

Heating and cooling are among the most important unit operations of the dairy and food industry since almost all the food material is heated or cooled for a variety of reasons in one stage or the other during processing.

These operations are carried out to get the desired properties of the food material during processing for enabling the efficient operations as the properties of the material are temperature dependent, to increase or decrease the reaction rate, to preserve the food material by lowering the temperature or moisture content as the microbial growth and decay as well as chemical and biochemical reactions depend on the temperature and moisture content, to remove heat developed in mechanical operation, to get the desired characteristics of final product, to assist further processing operations, etc. (Kumbhar *et al.*,1985).

The equipment which are generally used to transfer thermal energy through a separating wall or by direct contact between two or more fluids are called heat exchangers. Scraped surface heat exchanger (SSHE) is more suitable for heat transfer for viscous and heat sensitive products. The mechanical action on the heating surface safe guards against fouling which

[1.] Assistant Professor, [2.] Professor and Head reduces the residence time distribution (RTD) and facilitates processing of difficult products. Flow patterns, mixing effects, residence time distribution, heat transfer and power requirements are the major parameters for design and performance evaluation of SSHE (Abichandani *et al.*, 1987 and Harrod, 1990). It is easier to control time, temperature and pressure in a SSHE than in a kettle (Alam, 1988). This makes it possible to achieve more even and improved quality in cooking of highly viscous products.

In India, many un-organized sectors manufacture indigenous milk products like basundi, peda, khoa etc. in open pan which involves lots of labour in preparation of these products. The use of SSHE for the manufacture of such product helps in reducing man power and improving quality as well as shelf life of the product (Rajshekhar *et al.*, 2001). To a great extent SSHE has replaced kettles for processing of fruit juices, jams, margarine, sugar concentrates and many other food products. It is reported that SSHEs are suitable for processing liquid food having suspended solid, high viscosity and non-Newtonian rheology (Christie and Shah, 1992; Dodeja *et al.*, 1992). Dodeja *et al.* (1989) reported the use of SSHE for the manufacture of UHT milk.

Application of SSHE for dairy industry

SSHE of various design are being used for manufacture of TIDP as well as for western product such as icecream, cheese etc. Manufacturing of various dairy products using scraped surface processing plant increases their shelf life (Rajorhia *et al.*,1991). The manufacturers of various SSHE have described the constructional and application of SSHE. (Anonymous, 1985). They include the coolmix (Fryma-Maschinen AG, Switzer land), Thermutator (Cherry- Burrel), Contherm (Alfa-Laval), Consistator (de Gesternberg, Denmark), Rota-pro(APV Crepa co), Fran Rica (USA) and Spiraflow (Heat Recovery System Ltd.,Watford UK). Applications claimed include UHT treatment of milk(Ready and Mathur,1991; Lewis,1993; Kjaerulff,1998), heating and cooling of various food products, protein concentrates, reconstituted milk, cream, ice cream, cheese, chocolate sauces and other viscous products (Abhichandani *et al.*,1989b; Ohlsoon, 1989), cooling molasses (Broadfoot *et al.*,1990), whey solids (Anon,1978), asceptic processing of fruits for yoghurt and icecream (Anon,1980, Smittcamp *et al.*, 1981), manufacture of khoa based sweets like gajar halwa, dudhi halwa, kheer (Upadhyay *et al.*,1993) and indigenous products like khoa, ghee(Bector *et al.*,1996). manufacture of ghee (Abhichandani *et al*, 1978, Savita and Dodeja, 2011), khoa (Dodeja *et al*, 1990a; Dodeja and Nand kisore,2011; Bhadania *et al.*, 2004a), UHT sterilization of milk (Abhichandani et al, 1978), Basudi (Rajshekhar *et al*, 2002; Patel Sunil, 2007; Dodeja; 2013), Milk evaporation(Kohli and Abhichandani, 1994), Rabri and Barafi (Dodeja, 2013), Sandesh (Patel and Bhadania,2004), Halwasan (Patel Sunil,2013).

Classification of heat exchangers and SSHEs

A large numbers of heat exchangers are available for heating and cooling operations in different industries such as dairy, food, chemical, pharmaceutical, etc. These heat exchangers can be classified in a number of ways such as according to transfer processes, degree of heat transfer, surface compactness, construction features, flow arrangements, number of fluids and heat transfer mechanism (Shah, 1981). In a direct contact type heat exchangers the heat is transferred through direct contact between hot and cold fluids; whereas in an indirect type, heat is transferred from hot fluid to cold fluid through a separating wall (Kumbhar *et al.*,1985). SSHEs are classified based on several ways such as scraper arrangement, blade clearance, design of product tube, etc. Abhichandani *et al.*, (1978) gave the detailed classification of SSHEs employed in dairy and food industries.

Factor affecting the selection and design of heat exchangers

The choice and design of heat exchanger depends on a large number of factors such as (1) Flow rate of both streams: The size-length, width, height, weight of any heat exchanger depends on the flow rates of both the streams. There may be limitations on the size of heat exchanger due to site requirement, lifting and servicing capabilities or inventory consideration. Therefore, accurate process flow are indispensable for sizing heat exchangers to meet required thermal thermal duties at the smallest pressure drop and to minimize capital cost (2) Heat sensitivity and corrosivity of the fluids: Some fluids are heat sensitive while some are corrosive in nature. Hold up volume, residence time and surface temperature are met by exchangers having good flow distribution, high heat transfer coefficient and small channel volumes. If the fluid is corrosive in nature, the corrosion resistant material should be used for construction. (3) Terminal temperatures: The performance of heat exchanger depends on the terminal temperature of the processed streams and is expressed in terms of number of heat transfer units. In general plate heat exchanger has more heat transfer units per pass than tubular heat exchanger. (4) Properties of both streams: Properties of fluid such as viscosity, thermal conductivity, density, specific heat etc. are used for determination of pumping and heat transfer rate. For low viscous fluid plate heat exchanger and for high viscous fluid SSHE is the best choice.(5) Operating pressure and temperature: Mechanical design of the exchanger depends on the operating temperature and pressure(6)Pressure drop: Pumping cost and heat transfer depends on pressure drop (7) Fouling tendencies: Velocity of the fluid, temperature of the surface on which foul forms, bulk fluid temperature and composition of the fluid affects the deposition of solid on the heat transfer surface. (8) Inspection-cleaning and extension possibilities: Heat exchanger should permit easy cleaning and inspection for fouling, leakage and corrosion. It should be possible to extend the exchanger to accommodate increased capacity of the dairy/food processing plant with minimum installation change and cost. (9) Type and phase of fluids: The choice depends on the viscosity of liquid and suspended solids. If condensable gas is to be used, tubular heat exchanger is the obvious choice (10) Material of construction: The type of material used for the construction of exchanger depends on the properties of the liquids, operating temperature and pressure, welding ease, availability, conformance to all applicable laws, codes and cost. SS 302, 304, 316 are used for the construction of the parts of equipments which directly come in contact with dairy/food materials. (11) Heat recovery: For heat recovery in excess of 50 %, the tubular heat exchanger will be seldomly used while plate heat exchanger can be used conveniently upto 95% heat recovery. (12) Flow arrangement: Counter current flow arrangement is thermodynamically superior, produces minimum thermal stress, takes minimum advantage of maximum advantage of the heat transfer surface, recurring the least heat transfer surface for given duty and maximum heat recovery (13)Cost of heat exchanger.

Scraped surface heat exchanger (SSHEs)

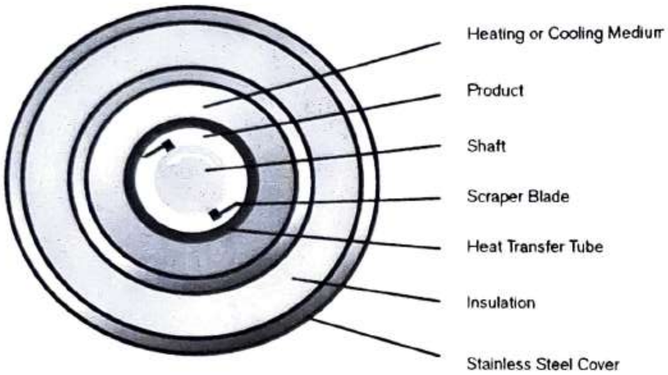
High viscosities and non-Newtonian behaviors of the processed fluids are often encountered in dairy and food field and tend to complicate their handling and to reduce the heat transfer rates in process equipment. In addition, the presence of solid food pieces causes additional problems related to the formation of solid deposits on hot surfaces. During heating, these deposits can eventually heat up to roasting temperatures altering the aromatic properties of the treated fluid. Some of these issues can be avoided or minimized by adopting a SSHE in place of shell and tubes or double-pipe heat exchangers. Unlike the simpler plate heat exchangers which are commonly used for low viscosity process fluids, SSHEs are designed to deal with the problems that arise when processing very viscous products. Foodstuffs such as margarine, ice-cream, chocolate, sauces, spreads, peanut butter, cream, caramel, purees, soups, salad dressings, yoghurt and jam are all routinely processed using SSHEs (Smith, *et al.*, 2010). The scraping action of the blades rotating within the heat transfer tube continuously removes the product film from the heat exchanger surface and prevents burning-on, scaling or crystal build up on the wall. During operation, the product is brought in contact with a heat transfer surface that is rapidly and continuously scraped there by exposing the surface to the passage of untreated product. More over the product is in contact with the heating surface for only a few seconds and high temperature gradient can be used without the danger of causing undesirable reactions. This type of heat exchangers can be used for batch or continuous heating or cooling of products with very high viscosity and solid contents up to 75 %. The major advantages of SSHE include short residence time in heated zone so heat sensitive product can be conveniently processed, high heat transfer coefficient, narrow residence time distribution, wide viscosity range, minimum surface fouling, liquids with foaming tendency can be easily handled, high capacity reduction-down to 10% of design throughput, low product inventory, waste heat recovery is possible for energy conservation, it is possible to use concentrated milk as feed which would increase the capacity substantially, efficient use of thermal energy, better process control and optimization (Abhichandani *et al.*,1978; Dodeja and Nand Kisore, 2011).

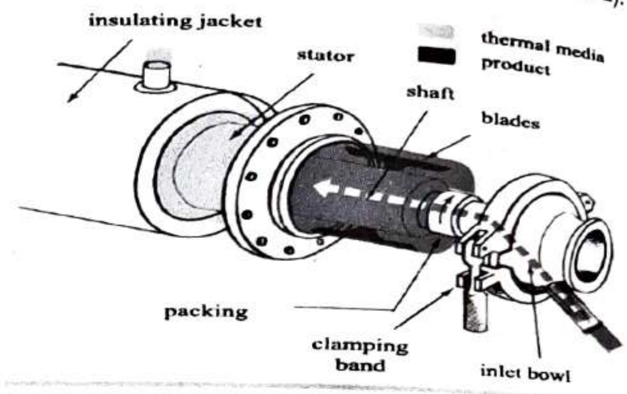
Parts and configuration of SSHE

SSHE basically consists of a cylindrical rotating shaft (the "rotor") within a concentric hollow stationary cylinder (the "stator") so as to form an annular region along which the process fluid is pumped.

1. Stator : The stator acts as the heat-transfer surface, and it is normally enclosed within another cylindrical tube which provides a gap through which a heating or cooling service fluid passes. Scraper fitted with two or more scraping blades mounted on the central shaft. The outer cylinder is covered with an insulated material to minimize heat loss to or heat gain from the surrounding. The stainless steel sheet with sealed joint is used to cover the insulation and protect it from mechanical damage. It is made up of stainless steel or mild steel lined with chrome nickel plating. The inlet and outlet ports for heating or cooling medium and liquid product are kept at the end of the cylinders.

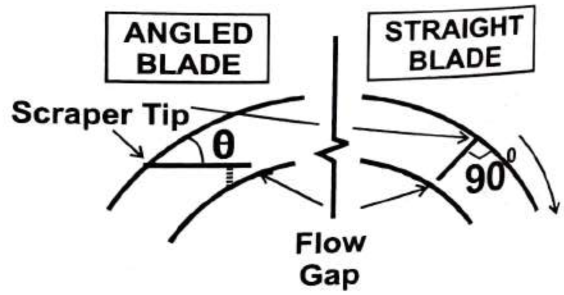
2. Rotor:SS rotor shaft at the center of the cylinder holds the scraper blades and connected to drive mechanism for rotation. Flow of milk through the pump can be regulated by varying the speed of feed pump and rotor speed can be controlled by with the help of variable frequency drive (VFD). Feed pump should handle viscous/non viscous fluids and pulped material in suspension, *viz.*, milk, cream, sugar syrup, beverages and fruit juices. It has a uniform pulse-free output in strict linear dependence on the rotational speed. SSHE must be insulated with glass wool or other appropriate insulating material of about 1-2.5 cm thickness. The dimensions of SSHE vary from 7.5 cm to 25 cm diameter and length of 120 to 180 cm (HE, 2012). Scraper assembly of appropriate design is configured for scraping action. Attached to the rotor are a number of pivoted blades each of which scrapes the heat-transfer surface, removing processed fluid and hence allowing unprocessed fluid to come closer to the stator. For maximum efficiency the product tube is manufactured from a material with a high heat-transfer coefficient. The blades themselves are usually made from stainless steel as well as Teflon material depending on the application (Smith, 1972).





Scraper Arrangement:

In a typical SSHE there are usually two or four blades located periodically around the rotor throughout the product tube, though sometimes they are axially staggered in order to improve mixing. The rotating scraper helps in improving efficiency, proper mixing and imparting desirable consistency and texture to the product. In ice cream freezer action of the blades helps to blend the fluid, air and ice crystals that are formed on the cooled stator surface, to produce a smooth consistency. The scraper may be grouped into fixed clearance scraper and variable clearance scraper. The fixed clearance scrapers are used for highly abrasive product such as sugar/fat mixture and are fitted with small clearance between the blades and the heat transfer surface of the inner cylinder. Variable clearance scrapers have floating blades which are forced towards the wall by spring, centrifugal force, hydrodynamic action of the fluid or a combination of these forces. The product velocity at the heat transfer surface depends on the speed of the scraper and the effective number of the rows of the blades and does not depend on the product flow rate. The overall thermal performance of the continuous *Khoa* making unit is improved by increasing the heat transfer rate with the help of blades by violently agitating the liquid, eliminating any channeling of liquid, decrease in apparent viscosity by shearing effect and forming a thin film of liquid on its heat transfer surface. The blade arrangement can be made in straight blades or staggered blades fashions. Dodeja *et al.*, (1987) reported that staggering of blades improved RTD and reduced power consumption as the flow is very close to plug flow that is free from bypassing, short circuiting and channeling. Kohli (1993) indicated that staggered blades for the concentration of milk are highly advantageous from viewpoint of heat transfer and hydrodynamics. It caused high turbulence due to more frequent interruption of fluid film by blades. Performance of SSHE machine with regards to heat transfer and product outflow for *khoa* have been reported (Bag, 1994).



Mode of Operation

Liquid-full operation and thin-film operations are very commonly used in SSHE. In liquid full operation, the vessel is filled completely with liquid products and it is almost always used in sensible heat transfer. In the liquid full vertical SSHE the product falls down along the inner side of vertical heat transfer tube by gravity. The heat transfer is promoted by rotation of blades that scrapes product off the surface of the heat transfer tube. Centrifugal force throws the product back on the tube. Evaporated vapour rises in the free space close to the rotor. The flow pattern in the liquid full scraped surface film evaporator cannot be expected to be similar to the flow pattern in an annulus with a rotating inner cylinder where the annulus is completely filled with liquid. In case of thin film operation, product tube does not run full, but the liquid flows in a thin film. This mode of operation is used when a change of phase takes place in the liquid product. Some time, it is necessary to operate SSHE under positive back pressure to get effective scraping action, to overcome product film viscosity or to keep the product in liquid state (Guevas, *et al.*, 1980). The problems like viscosity variation, heat sensitivity and foaming encountered during processing of food products can easily be handled in thin film SSHE. Heat transfer in thin film SSHE is very complex involving hydrodynamic of the liquid, several empirical relations and operating variables etc. (Rajshekhar *et al.*, 2002).

Operating/ process parameters

Time, temperature and pressure are easily controlled in SSHE than a kettle (Alam, 1988). The geometry and operating parameters play a major role in heat transfer performance and quality of the product. The maximum operating flow rate of 2.7 x 10^4 l/h, maximum operating pressure of 35 kg/cm^2, maximum operating temperature of 250^{0}C have been reported (Pelsoi, 1972, Kumbhar *et al.*,1985, HE, 2012). Pressure drop is extremely important parameter in SSHE design since pumping cost and heat transfer rate depend on the pressure drop (Alfa laval, 1985). The operating steam pressure during manufacture of batch type khoa making process (Bhadania, *et al.*, 2004b), continuous khoa making machine (Dodeja, *et al.*, 1990b), basudi making machine (Patel Sunil,2007), thermization of shrikhand (Dhotre *et al.*, 2009), sandesh manufacture(Patel,2004), halwasan making(Patel Sunil, 2013) using various types of SSHEs with different types of scraper assembly have been reported.

Heat transfer behaviour of SSHE (Thermal design)

Heat transfer behavior of SSHE is very complex phenomena, as several factors such as properties of fluid being handled and operating parameters like temperatures, batch size, rotor speed etc. are associated with heat transfer (Trommelen and Beek, 1971; Harrod, 1990, Dumont *et.al.*, 2000.; Rajshekhar *et al.*, 2002). The rate of heat transfer between the heat transfer medium and the product is controlled by two mechanism viz. the rate of heat conduction in to the thin product layer at the heating surface as well as the rate at which the thin product layer is removed and then mixed with the bulk product. The mixing step occurs at radial mixing, which enhances heat transfer. However, axial mixing with a certain amount of back mixing may also occur, which leads to reduction in driving force and affects the heat transfer coefficient. The flow is three-dimensional (comprising a transverse flow driven by the moving rotor and blades and a pressure-driven axial flow) and in certain circumstances it can be complicated by the formation of vortices. The flow is also non-isothermal and will typically involve conduction, convection and viscous dissipation within the process fluid; moreover, the thermal characteristics of the service fluid may also affect the heat transfer. The fluids that are processed are often non-Newtonian, inhomogeneous, viscoplastic, viscoelastic, contain particulates, possess temperature-dependent viscosities, and/or undergo phase changes during the cycle through the SSHE which have impact on rate of heat transfer (Trommelen and Beek, 1971; Harrod, 1990 and Dumont *et al.*, 2000).

Overall heat transfer coefficient (U-value)

The overall heat transfer coefficient represents the intensity of heat transfer from one fluid to another through a wall separating them expressed as W/m^2 ^{0}C. The U-value is dependent on steam side film heat transfer co-efficient (ho), product side film heat transfer co-efficient (hi) and wall heat transfer coefficient (hw) (Patel and Bhadania, 2004). The value of hw is constant as it is fixed with the design of the SSHE. The resistance of heat transfer will be greater on product side than on condensing steam side (Mc Admas, 1954; Cuevas and Cheeryan, 1982). Heat and mass transfer equations are used in order to calculate the U-values of SSHEs (Kessler, 1981; Patel and Bhadania, 2004; Savita and Dodeja, 2011). The equation correlating operating temperature, TS, velocity of fluids, and number of blades for determining U value during evaporation of milk have been reported (Dodeja and Nand Kisore, 2011; Abhichandani, 1985).

The equation for calculating U value during preparation of khoa and evaporation of milk have been reported for cylindrical SSHE (Cuevas and Cheryan, 1982, Bhadania *et al.*, 2004a). The U value is a function of blade rotational speed and mass flow rate, number of blades, temperature, feed rate, steam pressure etc. (Cuevas and Cheeryan, 1982; Dodeja *et al.*, 1989; Dodeja *et al.*, 1990a; Punijrath *et al*,. 1990; Patel, 1990; Bhadania *et al.*, 2004b).

Calculation of hi value

The calculation of inner side(product side) film heat transfer coefficient(hi) during heating, evaporation of water using different type of SSHEs have been reported (Kessler, 1981, Patel and Bhadania, 2004, Savita and Dodeja, 2011). The product side film film heat transfer coefficient depends on various operating conditions of the SSHE such as scraper speed, concentration of the milk, design of the scraper etc. (Bhadania *et al.*, 2004a).

Dimensional Analysis

Dimensional Analysis is a mathematical technique used to develop correlation among various variables involved in a forced convection phenomenon in SSHE like film co efficient, dynamic viscosity, diameter, density, velocity, specific heat of fluid, thermal conductivity of fluid. If the number of variables involved in a physical process are known, then the relation among the variable can be determined (Bansal, 1983). This method can be adopted to all types of fluid resistance, heat flow problems and many other problems. The equation produced by this method also gives non dimensional constant, which governs the problem under consideration (Kessler, 1981; Patel, 2007). As the convection heat transfer is very complex, it is possible to investigate the combined effect of various operating parameters using dimensional analysis (Trommelen and Beek, 1971). Various researchers have developed different corelationships of variables based on dimensional analysis for evaluating the heat transfer behavior of SSHE (Skelland, 1958; Lateinen, 1958; Harriot, 1959; Das and Verma,1985; Abhichandani and Sarma, 1988a; Dodeja, 1987; Dodeja *et al.*, 1990b, Badshah ,1999). Krischbaum and Dieter (1958) developed corelationship for evaporation process and showed that scraped heat transfer coefficient decreased with increasing "T at constant rotor speed, low flow rate and higher value of "T. The study conducted by Reay (1963) showed that, heat transfer coefficient dropped by 20% when clearance was doubled and increased by 20% when clearance was decreased by 80%. It has been suggested that axial flow velocities were a better marker of thin film operation than rotational velocities (Bott and Sheikh 1966; Bott and Azoory; 1969; Azoory and Bott, 1970). Abichandani (1985) evaluated the heat transfer performance of water, buffalo milk and cream at different flow rate, scraper speed, number of blades and operating steam temperature. Goede and Jong (1993) predicted higher heat transfer coefficients due to scraping action than predicted by penetration theory. Dumont *et al.* (2000) studied the influence of flow regimes on temperature heterogeneity in a SSHE. Using non-Newtonian and Newtonian fluids, they observed large heterogeneities for laminar flow and progressive homogenization of temperature from inlet to outlet for high rotational speeds.

Calculation of ho value

Film heat transfer coefficient of working fluid side (ho) has been studied by various workers (Sativa and Dodeja, 2011; Kessler, 1981). Nusselt theory is applied to find the steam side film heat transfer coefficient (Kreith and Bohn, 1986; Patel and Bhadania, 2004, Bhadania *et al.*, 2004). Many research workers have reported values of ho during preparation of various indigenous dairy products using steam as heating medium (Dodeja, *et al.*,1990b; Patel, 2004; Patel Sunil, 2007; Dhotre *et al.*, 2009).

Energy Requirement for SSHE

Thermal and electrical energy are required in operations of SSHE. The manufacture of Traditional Indian Dairy Product involves heating and concentration of milk which require considerable amount of energy (Bhadania *et al.*, 2013). The electrical energy required for driving the rotor is very small (<0.5%) as compared to the steam (thermal energy) required to evaporate the water (Cuevas and Cheryan., 1982; Abhichandani and Sarma, 1988b&c; Dodeja *et al.*, 1989). The consumption of heat energy for the SSHE was 35147.8 W and electric power requirement was 324.48 W which was just 0.92 % of the thermal energy used during manufacture of khoa.(Bhadania, *et al.*, 2005).

Power required driving the rotor

The power required to drive the rotor of SSHE under various operating conditions have been reported by several workers (Trommelenand Boerema, 1966; Bhatacharya, 1970; Abhichandani and Sarma, 1988b&c; Abhichandani and Sarma, 1989a). The electric power requirement is associated with several factors like properties of material, speed of rotation, weight of scraper blades, geometry of SSHE, tension of springs, etc.(Bhadania, *et al.*, 2005). Abichandani and Sarma (1988b&c and 1989a) developed a relationship to predict the power requirement for SSHE using mathematical model. Altiokka (1992) found that the power consumption of SSHE is proportional to the rotational speed of the shaft and SSHE with no clearance had approximately 30% more power consumption than one with standard clearance. Electrical energy was found 0.10 to 0.25 kWh per kg water evaporated from milk for manufacture of khoa and 4 kWh for 50lit/h milk capacity (Bhadania, *et al.*, 2013).

Thermal energy requirement

In SSHE, vapour removal from the product is likely to accumulate on the top surface at the exit. The provision of induced draught system will quickly remove the water vapour from SSHE exit. Kohli and Serma (1990) reported heat consumption per kg of butter was maximum 187 kcal/kg in falling film SSHE as compared to 293 kcal/kg in case of jacketed kettle. Energy requirement for ghee making was 0.35 kg of steam/ kg of ghee in continuous process as compare to 0.68 kg of steam per kg of ghee in traditional method (Pandya,1998). The steam consumption in horizontal SSHE for sandesh making ranged from 1.795 to 6.75 kg steam /h in different operating conditions (Patel, 2003), 1.2 to 1.3 kg steam/kg of water evaporated for manufacture of khoa (Dodeja *et al.*, 1989) and 1.368 kg steam per kg water evaporated (Bhadania *et al.*, 2005).The steam consumption of continuous basudi making machine was 1.2 kg steam per kg water evaporated (Patel, 2007). The reported value of LPG consumption for thermization of Shrikhand ranged between 0.5 to 1.25 kg/h (Dhotre *et al.*, 2009).

Mass transfer in SSHE

Mass balance is carried out to determine the rate of evaporation of water from each stage and amount of steam consumption for each stage of SSHE. Mass balance is done on solid side and liquid side for the product (Abhichandani and Sarma, 1988a; Bhadania *et al.*, 2013).

Structural design SSHE

It includes the calculation of size, shape and strength of each component of the SSHE to handle the product efficiently, material of construction require to meet the requirements from the view point of food hygiene and sensory attributes of the product, the finish of the surface and the mechanical power to run the unit successfully and efficiently (Dhotre *et al.*, 2006). Shaft diameter, torque, cylinder thickness and motor power requirement can be calculated by applying various mechanical design principle /theory (Pandya and Shah, 2002; Khurmi and Gupta, 1992). The material for Product tube: SS 304 or 316 grade, Shaft:SS ,Blade: SS and Teflon ,Insulation: Glass wool and PUF is generally used.

Maintenance of SSHE

All the metallic parts that come in contact with the product should be made of SS and the non metallic parts coming in contact with product should be nontoxic, non-corrosive to product as well as cleaning solutions. The joints and welds of the system should be precise especially of the jacket. The entire corner should be well ground and polished. (Dhotre *et al.*,2006). The vertical installation requires less floor area as horizontal SSHE. Rajshekhar *et al.* (2001) has reviewed maintenance aspects of various components and accessories of SSHEs.

Advances in SSHE

More advanced designs of SSHE include features such as holes in the blades (which reduce power consumption), oval stators (which reduce "channelling" in which fluid passes through the exchanger relatively

unprocessed), and non-centrally mounted shafts (which enhance mixing and prevent material from building up on the underside of the blades).Forward and backward tapering and Step arrangement of SSHE cylinder is also an advance design of SSHE. Rotating disc or cone type (Screw type) with advanced instrumentation (Magnetic flow meter, pressure gauge, I/P converter, Transmitters, Pneumatic valves, Air pressure indicators, Digital panel meter, Process controller)plays an important role in process control and automation for continuously monitoring the process variables in SSHE. The latest version of industrial SSHEs are CONTHERM, CENTHERM, CONVAP and VOTATOR advanced design features are being manufactured by different manufacturer for dairy and food products.

CONCLUSION

Efficient heating or cooling of complex fluids is an important requirement for several operations in dairy and food industry. SSHE is more suitable for heat transfer to viscous and heat sensitive products. It is easier to control time, temperature, speed and pressure in SSHE as compared to other type of heat exchangers. This makes it possible to achieve more even and improved quality in cooking of products. The scraping blade continuously removes fouling and eliminates burn-on problems as well as improves heat transfer rates. Manufacture of various dairy and food products using scraped surface processing plant increases their shelf-life. Due to its vast application the importance of SSHEs is increasing day to day. Various researchers have used various theory and principles to established various operating parameters relationship for thermal design and power requirement of SSHE for dairy products. It is very important to improve the thermal efficiency to get overall economy of the SSHE system. There is a good scope for SSHE to prepare indigenous milk products *viz.,* basundi, peda, khoa, halava or in general any khoa based sweets on commercial basis. For improving the performance of SSHE follow the recommended procedure for manual as well as CIP cleaning. Adopt preventive maintenance schedule for bearings and other components of the SSHE. Follow the burr removal procedure periodically and replacement of blades. Adopt preventive maintenance schedule for bearings and other components of the SSHE. O-ring of the flanges should be cleaned with alcohol, clean O-ring groove with a wire brush. Replace the worn and damaged O-rings in pairs. For leakage proof operation, the running surfaces are precision lapped or polished, absolutely flat and parallel and the pressure holding the running surface should be sufficient.

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Impediments faced by the groundnut growers in adoption of recommended *kharif* groundnut production technology

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ABSTRACT

Groundnut being one of the important oilseed crop in Banaskantha district. The area under kharif groundnut is increasing year by year, but the production is not increasing. The average yield of farm level is always lower than yield obtained in FLDs. There is a wide gap between the farmer yield and FLD yield. This means that the groundnut crop has still potentiality to increase the productivity. This comparatively low productivity of kharif groundnut crop may be governed by many factors including adoption as well as many hindrances in the farmer's field situation. The present study was undertaken in Banaskantha district as having large area and more production under kharif groundnut in North Gujarat. Three talukas viz., Deesa, Dhanera and Dantiwada were selected purposively having higher area under kharif groundnut cultivation in the district. Five villages from each selected talukas and 10 farmers from each village were selected randomly. Hence final sample consists of 150 farmers. The major constraints faced by the groundnut growers in adoption of recommended kharif groundnut production technology were; high cost of input (96.67%), high wages of labour (92.00%), high cost of seed (85.33%) and lack of pure and good quality seed (80.00%).The suggestions offered by the groundnut growers to overcome the constrains faced by them in adoption of recommended kharif groundnut production technology were; certified seeds should be freely available from the market and co-operative society (94.67%), reasonable price should be given to agricultural produce (82.00%) and price of inputs should be minimized (65.33%).

Key words : Adoption, constraints, groundnut

Agriculture forms the backbone of Indian economy. Since last three decades, visible changes have been brought in agriculture in form of green and white revolution. This become possible mainly through coordinated research efforts, extension activities and irrigation facilities created. As a result, the country has achieved self-sufficiency in food grain production (green revolution) and milk production (white revolution) while, we are about to attain self-sufficiency in oil seeds production (yellow revolution).

Being agriculture based economy of the country, different crops like, cereal crops, fibre crops,oil seed crops, legume crops, fruits and vegetables crops *etc.* are grown in our country. Among all these crops, oil seed crops have a specific place in Indian agriculture. Oilseed crops comprising groundnut, sunflower, rapeseed and mustard, safflower, sesamum, niger, linseed, soybean, castor *etc.*, are important on global basis which play a pivotal role in agriculture, industry and export trade of India. Oilseed crops occupy an important place in Indian economy next to food grains. India occupies a premier position in the world oilseed scenario accounting 19.00 per cent of oilseeds areas with 9.00 per cent of production. Among the oilseed crops, groundnut is an important edible oilseed crop and ranks first in the world in respect of area, production and productivity of groundnut. Gujarat is one of the leading groundnut growing states of the country. The average area under ground nut crop was 14,54,000 ha and productivity of groundnut was 1398 kg/ha in Gujarat. (Anonymus, 2012b)

Groundnut is going to be the important oilseed crop in Banaskantha district. The average yield of Banaskantha district was 1319 kg/ha. The area under *kharif* groundnut in this district was 39,425 ha. during

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2012-13 (Anonymous, 2013). But the harvested yield of groundnut crop in the FLD was recorded as 2400 kg/ha.(Anonymous (2012a). This means that the groundnut crop has still potentiality to increase the productivity. This comparatively low productivity of *kharif* groundnut crop may be governed by many factors including adoption as well as many hindrances in the farmer's field situation. The study was conducted with the following objectives :

[1] To identify the constraints faced by the groundnut growers in adoption of recommended *kharif* groundnut production technology.

[2] To seek the suggestion from the groundnut growers to overcome the constraints faced by them in adoption of recommended *kharif* groundnut production technology.

METHODOLOGY

Ex-post facto research design was used for the study (Kerlinger, 1976). Banaskantha district of Gujarat state was selected purposively as groundnut crop has covered large cultivation area in the district and is increasing year by year. Three talukas *viz.,* Deesa (19,725 ha.), Dhanera (10,000 ha.) and Dantiwada (4,000 ha.) were selected purposively from district as these talukas were having higher area under *kharif* groundnut cultivation. Five villages were selected randomly from the list of groundnut growing villages from each taluka under *kharif* groundnut cultivation. Thus, total fifteen villages were selected. From each selected villages, ten groundnut growers were selected randomly. Hence, the final sample size was 150 groundnut growers from 15 villages.

Based on an extensive review of literature, consultation with extension personnel and experts of the subject, some important variables *viz.,* age, education, family size, social participation, land holding, annual income, extension participation, sources of information, cropping pattern, yield index and farm mechanization were selected as independent variables. They were measured with the help of the scales and indices developed by past researchers as well as structured schedules/tests which were framed for the purpose. Constraints were measured by asking to the groundnut growers to state the constraints faced in adoption of recommended *kharif* groundnut production technology. The frequency and percentage for all the constraints were calculated and then ranked accordingly. At the same time, the suggestions were collected from the groundnut growers to overcome the constraints they faced in adoption of recommended *kharif* groundnut production technology. Information collected was tabulated based on frequency and percentage and ranks were assigned to them.

RESULTS AND DISCUSSION

Constraints faced by groundnut growers in adoption of recommended kharif groundnut production technology

The groundnut growers might be facing certain problems in adoption of recommended *kharif* groundnut production technology. Due to such constraints, they cannot be adopt all the technology and hence could not make the groundnut crop profitable. The constraints in adoption of new technology never end. Hence, it was felt imperative to identify the constraints faced by the groundnut growers in adoption of recommended *kharif* groundnut production technology.

The respondents asked to give the constraints faced by them in adoption of recommended *kharif* groundnut production technology. The information was collected, tabulated and frequency and percentage for each constraint was calculated. Then, the ranks were assigned to the constraints and the data are presented in Table 1.

Data in Table 1 indicated that the major constraints faced by the groundnut growers in adoption of recommended *kharif* groundnut production technology were; high cost of inputs (96.67%), high wages of labour (92.00%), high cost of seed (85.33%), lack of pure and good quality seed/certified seed (80.00%), non-availability of sufficient labour in time (72.00%) and lack of use of improved implements (70.00%) and which were ranked one to six, respectively. The probable reasons of above constraints might be the groundnut crop require more quantity of seed and other inputs with high their rates, involves high labour requirements in agronomic practice and harvesting and farmers were not using improved implements.

Whereas non-remunerative price (64.67%), inadequate credit (56.67%), lack of storage facility (44.67%) and lack of timely and appropriate extension services (41.33%) were ranked seven to ten, respectively. While, lack of knowledge about recommended groundnut production technology (33.33%), lack of knowledge about storage (10.00%) and lack of knowledge about selling (5.33%) which were ranked eleven to thirteen, respectively. It can be inferred from the above results that high cost of inputs, high wages of labour, irregularity in crop production price, high cost of seed, lack of pure and good quality seed/certified seed, were the main constraints. These findings are in agreement with the findings of Patel (2005) and Desai 2013.

Suggestions from the groundnut growers to overcome the constraints faced by them in adoption of recommended kharif groundnut production technology
An attempt was made in this study to seek the suggestions from the groundnut growers to overcome the constraints faced by them in adoption of recommended *kharif* groundnut production technology. The respondents were asked to suggest possible solution to overcome the constraints, the information received was tabulated and frequency and percentage for each suggestion were calculated. Then, the suggestions were ranked accordingly and presented in Table 2.

Table 1 Constraints faced by groundnut growers in adoption of recommended groundnut production technology (n=150)

Sr. No.	Constraints	Frequency	Per cent	Rank
1.	High cost of inputs (fertilizer, insecticides, pesticides, herbicide etc.)	145	96.67	I
2.	High wages of labour	138	92.00	II
3.	High cost of seed	128	85.33	III
4.	Lack of pure and good quality seed/certified seed	120	80.00	IV
5.	Non-availability of sufficient labour in time	108	72.00	V
6.	Lack of improved implements	105	70.00	VI
7.	Non-remunerative price	97	64.67	VII
8.	Inadequate credit	85	56.67	VIII
9.	Lack of storage facility	67	44.66	IX
10.	Lack of timely and appropriate extension services	62	41.33	X
11.	Lack of knowledge about recommended groundnut production technology	50	33.33	XI
12.	Lack of knowledge about storage	15	10.00	XII
13.	Lack of knowledge about selling	8	5.33	XIII

Table 2 indicated that the suggestions expressed by groundnut growers to overcome the constraints faced by them in adoption of recommended *kharif* groundnut production technology. These were; certified seed should be freely available from market and co-operative society (94.67%), remunerative market price should be given for the produce (82.00%), price of inputs should be minimised (65.33%), timely technical guidance should be provided (49.33%) and crop loan should be provided enough to meet the increased cost of cultivation (46.00%) which were ranked as one to five,

Table 2 Suggestions of the groundnut growers to overcome the constraints faced by them in extent of adoption (n = 150)

Sr. No.	Constraints	Frequency	Per cent	Rank
1.	Pure and good quality certified seed should be easily available from market and co-operative society	142	94.67	I
2.	Reasonable price should be given to agricultural produce	123	82.00	II
3.	Price of inputs should be minimised	98	65.33	III
4.	Timely technical guidance should be provided	74	49.33	IV
5.	Adequate crop loan should be provided to the farmer	69	46.00	V

respectively. From the above results, the important suggestions expressed by the groundnut growers were; certified seeds should be easily available from market and co-operative society, reasonable price should be given to agricultural produce and price of crop should be reasonable.

CONCLUSION

The major constraints faced by the groundnut growers in adoption of recommended *kharif* groundnut production technology were; high cost of input (96.67%), high wages of labour (92.00 %), high cost of seed (85.33 %), lack of pure and good quality seed/certified seed (80.00%), non-availability of sufficient labour in time (72.00%), lack of improved implements (70.00%) according to the order of importance. The suggestions given by the groundnut growers to overcome the constraints faced in adoption of recommended *kharif* groundnut production technology were; certified seed should be easily available from co-operative society and market (94.67%), reasonable price should be given for produce (82.00%), price of inputs should be minimized (65.33%) which were ranked accordingly.

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Variability study in medicinal and aromatic crop field experiments and yardstick there of

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ABSTRACT

The data on CV per cent for Medicinal and aromatic crop yield along with other details of 535 field experiments conducted during 1989-90 to 2011-12 at Main Research Station, Medicinal and Aromatic crop, Anand Agricultural University, Anand were collected and analyzed. Most of the experiments carried out in plant breeding (257) and Agronomy (216) disciplines. More than 80 % experiments carried out in RBD and about 23 % experiments of them have CV per cent higher than the fiducial limit (22.65 %). Treatments group 6-10, 11-15 and 16-20 showed lower CV per cent compared to overall average CV per cent. Plot size of the experiments 3 to 12 sq. mt. seems to be optimum plot size for medicinal and aromatic crops. Majority experiments were conducted with 3 and 4 replications in field experiments on Medicinal and Aromatic crops in which about 22 percent were having CV per cent > 22.65. The frequency distribution tables were prepared for various experimental factors. The upper fiducial limits (the yardstick) of CV per cent at 95% confidence based on non central't' distribution were worked out for accepting the results of Medicinal and aromatic crop experiments which emerged as 23%.

Key words : Fiducial limit, plot size, non central t distribution, experimental variability

Statistics are used to interpret data and sometimes to determine whether data are suspect. Most researchers are familiar with the use of the least significant difference (LSD) needed to separate two or more means. Another statistical measurement familiar to many scientists and taught in most basic statistics course is the coefficient of variation or the CV. This familiar measurement was created in the late 1800s as a measure of population variability. However, ever since it was tacitly promoted as a measure of experimental validity by (Snedecor and Cochran, 1967) its original purpose has been largely ignored. The experimental data provide information on controlled (treatment effect) and uncontrolled variation. The uncontrolled variation is expressed as experimental error, which could be quantified as an estimate called 'coefficient of variation (CV)'. In agricultural field experiments variation occurs due to uncontrolled factors such as soil heterogeneous, types of crop, climatic factors etc. and controlled factors such as field layout, treatments, replications, plot size etc. Therefore CV of field experiments varies with the situation. Lower magnitude of CV is the reflection of reliability (precision) of the experimental results. The acceptable range of CV advocated by various workers is based on the experience with very limited number of experiments. There need to develop a yardstick (critical value) for CV based on theory and also on a large number of experiments conducted under different situations. The present paper deals with this aspect. (Johnson and Welch, 1939) reported that for a normal distribution, the ratio of mean to standard deviation should be of the order of 3 or more. Further, they mentioned that 33% has often been stated as the permissible upper fiducial limit of CV. (Tyagi *et al.*,1973 and Patel *et al.*, 1978) pointed out that CV obtained for the crops under study was found to be considerably higher than those reported from the uniformity trials. They stated that the yardstick for accepting experimental results should be worked out using CV observed in the experiments rather than in the uniformity trials. (Bajpai and Nigam, 1980) suggested a working rule for deciding the value of *W2*

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(weight corresponds to precision of the experiment) and developed an index to evaluate agricultural field experiments statistically. (Gomez and Gomez, 1984) reported that CV varies greatly with the type of experiment, the crop grown and the character measured. They pointed out that the acceptable range of CV is 6 to 8 % for varietal trials, 10 to 12 % for fertilizer trials and 13 to 15% for insecticidal and herbicidal trials on rice. (Patel *et al.*, 2000), reported that the coefficient of variation in pulse experiments in RCBD exceeds 23 %, the experimental findings should not be considered for any purpose. (Snedecor and Cochran, 1967) they stated, "a knowledge of relative variation is valuable in evaluating experiments." They go on to say the coefficient of variation of the yield of hay is comparable to that of the yield of corn." Consequently, the CV has been used as a measure of validity for many types of agricultural experiments, from fertilizer experiments to crop performance trials. (Kendall and Stuart, 1977) they reported that CV was created as a measure of relative variability. (Aflakpui, 1995) states that "there is no such thing as a CV for an experiment, only for individual variates." However, a CV of 10 to 15% for yield in experiments is generally expected by most field crop researchers. (Cochran and Cox's, 1957) stated that "the coefficient of variation is often between 5% and 15%." The basis for the CV is the assumption that the variance increases as the size of the mean increases. (Allen *et al.*, 1978) reported a positive relationship for several crops, and (Gotoh and Osanai, 1959) reported a positive relationship for wheat. (Masood and Javed, 2003) reported based on the coefficients of variation the optimum plot sizes for maize trials were estimated to be (14.06 m^2) with square shape. (Khan and Mead, 1998) presented uniformity data from field trials for improving precision of agriculture field experiments in Pakistan. (Darji *et al.*, 2010), developed the yardstick of CV per cent for forage crop experiment at 95 % confidence based on non central 't' distribution were worked out for accepting the results of forage crop experiments which emerged as 14 %.

MATERIALS AND METHODS

The secondary data of CV per cent for yield character was compiled on Medicinal and aromatic crop of 535 field experiments conducted at Main Research Station, Medicinal and Aromatic crop, Anand Agricultural University, Anand during 1989-90 to 2011-12 in plant breeding, agronomy, plant protection, plant physiology and plant pathology disciplines on different Medicinal and aromatic crops viz. Aloe (1), Asalio (1), Ashwagandha (106), Basil (7), Bhumi amali (3), Cress (9), Dodi (21), Glycyrhiza (7), Isabgul (159), Kalmegh (34), Liquorice (19), Madhunashi (3), Periwinkle (10), Safed musali (99), Senna (44), Shankhpushpi (11) crops were utilized for the variability study. Information on plot size, number of treatments, replications, experimental design and disciplines were collected for each experiment.

The plot-wise yield data were subjected to statistical analysis and CV was estimated for individual experiment. The same was assumed as random variable in further analysis. CV is a function of square root of mean square (S) and mean ($\bar{X}$).

$$CV=\frac{S}{\bar{X}} \tag{1}$$

The distributions of $\bar{X}$ and S have simple forms and Student's t distribution provides complete solution for testing the hypothesis or estimating fiducial limits relating to either m or s, singly. But t distribution cannot be used for $CV=\frac{s}{\bar{x}}$. (Mckay, 1932) used non-central t-distribution for providing fiducial limits of CV.

Let z be a quantity distributed normally about zero mean with unit standard deviation and let w be a quantity distributed independently as x^2, with degrees of freedom of x^2. Then, if t is defined by the equation:

$$t=\frac{Z+\delta}{\sqrt{W}} \tag{2}$$

Where d is some constant, then t is distributed in a manner depending only on d and f. This distribution is a non central t-distribution. When d equals zero, the distribution is the familiar Student's t.

Let an estimate of V be $v= S/\bar{X}$ the sample coefficient of variation.

Now, one may write

$$\frac{\sqrt{n}}{v}=\frac{\sqrt{n}\bar{X}}{S}=\frac{\sqrt{n}(\bar{X}-\mu)}{\sigma}+\frac{\sqrt{n}\mu}{\sigma}+\frac{S}{\sigma} \tag{3}$$

It appears from comparison with eq. (2) that $\frac{\sqrt{n}}{V}$ is distributed as non-central t with $f = (n-1)$ and $\frac{\sigma\sqrt{n}}{V}$. This distribution can be used for test of significance and for providing fiducial limits of V (*i.e.*, CV), as is done for μ. Since the objective was to work out the yardstick based on CV, the upper fiducial limit of CV using non-central t-distribution was estimated following the procedure given by (Johnson and Welch, 1939).

The procedure is briefly explained below. Let,

(1) $$CV = \frac{\sqrt{Error\ mean\ square}}{General\ mean}$$

n = number of treatments $\times$ number of replications in a given experiment, $f = n-1$ degrees of freedom.

Now, the upper fiducial limit of CV is,

$$CV_{UL} = \frac{\sqrt{n}}{\delta}(f,\ t_o\ \varepsilon)$$

Where, $$t_o = \frac{\sqrt{n}}{CV}$$

(2) Find $$Y = \left[1 + \frac{t_0^2}{2f}\right]^{-1/2}$$

or

$$Y' = \frac{t_0}{\sqrt{2f}}\left[1 + \frac{t_0^2}{2f}\right]^{-1/2}$$

According to whether $\frac{t_0}{\sqrt{2f}}$ is greater than or less than 0.75. Consider Y', if $\frac{t_0}{\sqrt{2f}}$ lies between -0.75 and 0.75, otherwise consider Y.

(iii) If $f > 9$, calculate $\frac{12}{\sqrt{f}}$

(iv) Select desired probability level of confidence, *i.e.*, and obtain $\lambda(f, t_0, \varepsilon)$ from the table in (Johnson and Welch, 1939) interpolating with respect to the quantities obtained in (ii) and (iii).

(v) Calculate

$$\delta(f, t_0, \varepsilon) = t_0 - \lambda\left[1 + \frac{t_0^2}{2f}\right]^{-1/2}$$

In the present investigation, the yardstick of CV for field experiments was worked out using two concepts: (i) average upper fiducial limit of CV for each of the 535 medicinal and aromatic crops field experiments was worked out separately and then average of these upper fiducial limits was computed, and (ii) upper fiducial limit of CV based on average size of experiments, i.e., degree of freedom. The upper fiducial limit of 95 % and 90 % worked out using the theory of truncated t distribution as described by (Johnson and Welch, 1939).

RESULTS AND DISCUSSION

The results presented in (Table 1) revealed that mean CV per cent (17.28) and upper fiducial limit (22.65) of average value of all the discipline except for plant physiology and plant protection discipline, were below the average CV per cent. The experiments on plant protection and plant physiology showed large variation (average CV = 26.32 % and 32.51 %) respectively showed poor precision may be because of experimental requirements such as sample size, natural population of pests and diseases. Use of proper statistical tools may help to improve the precision of the results. More than 50% experiments of this disciplines had more than 22.65%.

The results presented in (Table 2) indicated that most of the experiments were carried out in RBD and FRBD and about 20 % of them had CV per cent higher than the fiducial limit worked out. This proportion was about 40 % in other designs (Except RBD and SPT).

Influence of number of treatments was also examined and results are given in (Table 3) according to different treatments group. More than 20 treatments in an experiment showed higher CV per cent than the overall average (17.28%).

Generally increased number of treatments in the experiments increases blocks (replication) size which increases error variance, affecting the precision of the results. Therefore, it is advisable to use such experimental designs (when treatment exceeds 16) which can help in controlling within block variation. Other means such as optimum plot size, more number of replications, proper site of the experiment etc. need to be considered. About 23 to 57 percent experiments showed higher CV per cent compared to the overall average CV per cent except the treatment group 11-15.

Table 1 Upper fiducial limit of CV per cent of experiments for different disciplines

Discipline	No. of experiments	Average C.V. %	Upper limit		Range		C.V. % > 22.65	
			(0.05)	(0.10)	(0.05)	(0.10)	No.of exp.	Proportion
Agronomy	216	16.81	22.04	20.69	5.23	3.88	45	0.20
Plant Breeding	257	16.31	21.24	19.97	4.93	3.66	53	0.20
Plant Physiology	15	26.32	37.55	34.50	11.23	8.18	8	0.53
Plant Protection	18	32.51	42.07	39.64	9.56	7.13	12	0.67
Plant Pathology	29	16.43	21.39	21.13	4.97	3.70	2	0.06
Average	535	17.28	22.65	21.26	-	-	-	-

Table 2 Upper fiducial limit of CV per cent of experiments for different design

Design name	No. of experiments	Average C.V. %	Upper limit		Range		C.V. % > 22.65	
			(0.05)	(0.10)	(0.05)	(0.10)	No.of exp.	Proportion
FRBD	89	16.56	20.40	19.46	3.84	2.90	17	0.19
RBD	427	17.46	23.21	21.71	5.75	4.25	100	0.23
SPT	14	16.51	20.34	19.41	3.84	2.90	2	0.14
Other	5	21.96	26.81	25.63	4.85	3.67	2	0.40
Average	535	17.28	22.65	21.26	-	-	-	-

Table 3 Upper fiducial limit of CV per cent of experiments for different treatments

Treatments	No. of experiments	Average C.V. %	Upper limit		Range		C.V. % > 22.65	
			(0.05)	(0.10)	(0.05)	(0.10)	No.of exp.	Proportion
Up to 5	129	17.38	24.25	24.41	6.87	5.03	30	0.23
6-10	221	17.22	22.93	21.45	5.71	4.23	52	0.23
11-15	116	16.97	21.13	20.11	4.16	3.14	19	0.16
16-20	56	16.99	20.52	19.67	3.53	2.68	14	0.25
21-25	00	–	–	–			0	00
26-30	7	24.11	27.84	26.99	3.74	2.88	4	0.57
>30	6	18.57	21.13	20.55	2.56	1.99	2	0.33
Average	535	17.28	22.65	21.26	-	-	-	-

The results presented in (Table 4) indicated that the average CV per cent for different plot size experiments were below the average CV per cent (17.28) in plot size 3 to 12 sq.mt. Beyond 12 sq.mt. plot size the proportion of CV per cent having higher CV per cent increased from 0.34 to 1.0. Therefore, plot size of 6 to 12 sq.mt. seems to be an optimum plot size for medicinal and aromatic crops. Therefore, this needs to be confirmed by plot technique study for different locations and crops.

Table 4 Upper fiducial limit of CV per cent of experiments for different plot size

Plot size (m^2)	No. of experiments	Average C.V. %	Upper limit		Range		C.V. % > 22.65	
			(0.05)	(0.10)	(0.05)	(0.10)	No.of exp.	Proportion
<3	35	18.91	24.70	23.20	5.78	4.29	13	0.37
3-6	169	15.61	20.37	19.15	4.76	3.54	26	0.15
6-9	138	16.81	22.13	20.76	5.33	3.96	32	0.23
9-12	128	16.67	21.60	20.33	4.93	3.65	26	0.20
12-15	23	21.00	27.97	26.16	6.97	5.16	8	0.34
15-18	38	23.57	31.15	29.19	7.58	5.62	14	0.36
18-21	2	15.47	18.34	17.63	2.86	2.17	0	00
21-24	0	–	–	–	–	–	0	00
>-24	2	42.08	63.84	57.66	21.76	15.58	2	1.00
Average	535	17.28	22.65	21.26	–	–	–	–

Table 5 Upper fiducial limit of CV per cent of experiments for different replications

Replication	No. of experiments	Average C.V. %	Upper limit		Range		C.V. % > 22.65	
			(0.05)	(0.10)	(0.05)	(0.10)	No.of exp.	Proportion
2	7	15.91	20.38	19.25	4.46	3.33	1	0.14
3	244	17.29	22.40	21.09	5.11	3.80	56	0.22
4	192	17.17	22.61	21.20	5.44	4.02	43	0.22
5	12	19.47	25.71	24.10	6.24	4.63	4	0.33
6	7	15.90	21.64	20.14	5.74	4.24	0	00
8	39	20.01	27.05	25.23	7.05	5.22	12	0.30
11	6	16.23	20.96	19.79	4.73	3.55	0	00
13	27	14.75	19.54	18.31	4.79	3.56	5	0.18
Average	535	17.28	22.65	21.26	–	–	–	–

As far as replications are concerned, the experiments conducted with 5 and 8 replications showed large variation and 33 and 30 per cent experiments showed CV > 22.65 respectively (Table 5). Analysis showed that majority experiments were conducted with 3 and 4 replications in field experiments on Medicinal and Aromatic crops in which about 22 percent were having CV per cent > 22.65.

Table 6 The average upper fiducial limit and yardstick for CV per cent for the experiments of Medicinal and Aromatic crops

Name of Crops	No. of experiments	Average C.V. %	Upper fiducial limit of C.V. %		Overall yardstick of C.V.%
			0.95	0.90	
Medicinal and Aromatic crop	535	17.28	22.65	21.26	23 %

The CV per cent data of 535 field experiments were used to fit non central 't' distribution to work out upper confidence limit of CV at 0.05 level of probability (Table 6). According to the upper fiducial limit of CV per cent at 95 percent confidence level of CV per cent was worked out to be 22.65 per cent. Thus the results suggested that about 23 percent CV per cent should be considered as a yard stick for Medicinal and Aromatic crop field experiments. These having CV per cent > 23 should be rejected for drawing valid scientific conclusion.

Table 7 Power of F-test as influence by CV per cent

Class C.V.%	No. of experiments	F-test		
		Significant	Not-Significant	Ratio
3.35-8.35	73	41	32	0.78
8.35-13.35	129	56	73	1.30
13.35-18.35	133	70	63	0.90
18.35-23.35	74	34	40	1.18
23.35-28.35	47	24	23	0.96
28.35-33.35	26	17	9	0.53
33.35-38.35	16	4	12	3.00
38.35-43.35	8	4	4	1.00
43.35-48.35	2	0	2	0.00
48.35-53.35	6	1	5	5.00
53.35-58.35	1	0	1	0.00
73.35-78.35	1	0	1	0.00
Total	516	251	265	1.06

The power of F test was examined with the not significant/ significant ratio of experiments (Table 7). The results revealed that the ratio consistently increased with the increase in CV of the experiments. It also indicated that the efficiency (of detecting difference in treatment means) of F-test decreased with the increase in CV of experiments. The average ratio was observed to be 1.06. The ratio for the class 13.35-18.35 % was almost equal to the average ratio which included 17.28 %, the average CV of all experiments results clearly showed that when the coefficient of variation in Medicinal and Aromatic crop field experiments exceeds 23 %, the experimental finding should not be considered for scientific purpose.

CONCLUSION

All the experiment results clearly showed that most of the Medicinal and Aromatic crops experiment carried out in plant breeding and agronomy disciplines, more than 80 % experiments conducted in RBD and, 6-10, 11-15 and 16-20 treatments group shows lower CV per cent as compared to overall average CV per cent. 3 to 12 sq.mt plot size seems to be optimum plot size and most of the experiments conducted with the 3 and 4 replications. When the coefficient of variation in Medicinal and Aromatic crops field experiments exceeds 23 %, the experimental finding should not be considered for any scientific purpose.

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