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CONTENTS

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STUDIES ON COMBINING ABILITY OVER ENVIRONMENTS FOR GRAIN YIELD, MORPHO-PHYSIOLOGICAL, NUTRITIONAL TRAITS IN PEARL MILLET (*Pennisetum glaucum* (L.) R. Br.)

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ABSTRACT

The experiment was conducted with 50 hybrids and fifteen parents which were developed through Line × Tester mating design using five male sterile lines and ten restorers as parental material evaluated over four seasons and pooled over seasons at Agricultural Research Station, Podalakur. Significant differences were observed for all the fifteen characters studied. Among fifteen parental inbred lines studied in pooled over seasons, the superior inbred lines *viz*., ICMR 13999, ICMR 100556 and ICMB 98222 identified based on mean performance, general combining ability effects may be utilized in the development of high yielding hybrids possessing earliness and enriched nutritional parameters and also that can fit well in different cropping windows. Among 50 hybrids studied in pooled over seasons, the superior hybrids ICMB 04999 × ICMR 100549 and ICMB 08666 × ICMR 13999 identified based on *per se* performance, *sca* and standard heterosis for grain yield and yield components over seasons could be recommended for commercial cultivation after extensive testing under MLT's / on-farm trials.

KEYWORDS: *Pennisetum glaucum*, Line × Tester mating design

INTRODUCTION

Pearl millet (*Pennisetum glaucum* (L.) R. Br.), is the fourth most important food grain crop after rice, wheat and sorghum in India. The contribution of pearl millet to the total Fe and Zn intake from all food sources has been reported to very widely vary across rural India. For instance, it was observed to be contributing 19-63 per cent of the total Fe intake and 16-56 per cent of the total Zn intake in parts of Rajasthan, Maharashtra and Gujarat states (Parthasarathy *et al.,* 2006). Constant efforts have been made to improve grain yield and its contributing characters through hybridization in pearl millet. Proper selection of parents is very crucial in planned hybridization programme. Combining ability provides useful information regarding the selection of suitable parents for effective hybridization programme and at the same time elucidates the nature and magnitude of different types of gene action. Since, the nature of gene action varies with genetic architecture of population involved in hybridization, it is necessary to evaluate the parents for their combining ability. This information enables the breeder to evaluate and classify selected parental material for their utility in development of high yielding F_1 hybrids in pearl millet, where hybrids are being cultivated on commercial scale. The current experiment was laid out comprising of fifty hybrids and fifteen parents of pearl millet to determine the combining ability for grain yield, Morpho-physiological and Nutritional traits.

MATERIAL AND METHODS

This trial was conducted with 50 hybrids, 5 lines and 10 testers in over pooled seasons at ARS, Podalakur in RBD replicated thrice. Every genotype was sown in one row of four meters length with 45 × 15 cm spacing. All management practices were followed as and when required to establish a good crop. Observations were recorded on 15 economically important characters viz., Days to 50% flowering, Days to maturity, productive tillers plant^{-1}, Plant height (cm), Panicle length (cm), Panicle girth (cm), 1000 grain weight (g), Grain yield (t ha^{-1}), Green fodder yield (t ha^{-1}), Dry fodder yield (t ha^{-1}), SPAD chlorophyll meter readings (60 DAS), Relative water content (%), Harvest index (%), Grain Fe content (ppm), Grain Zn content (ppm). Data from all the characters studied were exposed to analysis of variance technique on the basis of model proposed by Panse and Sukhatme (1967). The analysis of variance (ANOVA)

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method, as described by Singh and Chowdary (1985), was used. The combining ability analysis was carried out according to the method suggested by Kempthorne (1957).

RESULTS AND DISCUSSION

Combining ability analysis is of vital importance in crops like pearl millet as it helps in identification of potential parents with good *gca* effects and hybrids with good *sca* effects (Sprague and Tatum, 1942). As a general rule, general combining ability (GCA) is the result of additive gene effects and additive × additive interaction which are fixable, while the specific combining ability (SCA) is the result of non- additive gene effects that includes dominance, epistasis and other interactions which are non-fixable (Jinks, 1954). Parents with desirable *gca* effects for the targeted characters can be used to accumulate favourable alleles by recombination and selection in evolving productive hybrids. Knowledge on the nature and magnitude of gene actions involved in the inheritance of various quantitative characters is important in developing an effective and sound breeding programme. The present investigation was carried out with an objective of identifying potential parents and specific cross combinations for yield and yield components under four seasons and pooled over seasons through combining ability.

Analysis of Variance for Combining Ability

Combining ability analysis was carried out utilising the mean data recorded on replication wise for all the 15 characters in 50 hybrids using L × T mating design separately for all the four seasons *viz., kharif* 2020 (E_1), late *kharif* 2020 (E_2), *rabi* 2020-21 (E_3) and *summer* (E_4) and pooled data over seasons. ANOVA for combining ability analysis for all the characters studied is presented in Table 1. Combining ability analysis indicated that mean sum of squares due to GCA, SCA and seasons were significant for all the characters studied in all four seasons.

Pooled analysis of variance for combining ability over four seasons is presented in Table 1. The variance components due to GCA, SCA and seasons showed the highly significant differences for all the characters. Mean sum of squares due to GCA × Seasons and the interaction of SCA × Seasons also exhibited significant differences for all characters. Significant mean sum squares due to seasons and GCA × Seasons and SCA × Seasons for yield and yield components indicate that both additive and non-additive genetic variances are greatly influenced by environments (Seasons).

The detailed results of combining ability effects and variances for all characters under consideration are presented here under season wise and pooled over seasons.

General Combining Ability (*gca*) Effects

A perusal of estimates of *gca* effects in pooled data analysis revealed that none of the parents tested were found to be the good general combiners for all the characters. However, a few parents showed desirable *gca* effects for most of the characters under study. ICMR 100549 is best suitable cultivar for number of productive tillers plant^{-1}, ICMR 08666 for plant height(cm) and green fodder yield (t ha^{-1}), ICMR 13999 for panicle length (cm), grain yield (t ha^{-1}) and Relative water content (%), ICMR 100549 for panicle girth (cm) and dry fodder yield (t ha^{-1}), ICMR 13999 for 1000 grain weight (g), days to 50% flowering and days to maturity, ICMB 98222 for SPAD chlorophyll meter readings (60 DAS), ICMR 100087 for harvest index (%) ICMR 12555 for Grain Fe content (ppm) and Grain Zn content (ppm).

Among the testers ICMR 100556 was identified as the best general combiner as it registered significant *gca* effects in desired direction for number of productive tillers plant^{-1}, plant height (cm), panicle girth (cm), 1000 grain weight (g), grain yield (t ha^{-1}), green fodder yield (t ha^{-1}), days to 50% flowering, days to maturity, SPAD chlorophyll meter reading (SCMR), relative water content (%), harvest index (%) and nutritional parameters grain Fe content (ppm) and grain Zn content (ppm). The tester parent ICMR 13999 registered significant *gca* effects in desired direction for number of productive tillers plant^{-1}, plant height (cm), panicle length (cm), panicle girth (cm), 1000 grain weight (g), grain yield (t ha^{-1}), green fodder yield (t ha^{-1}), dry fodder yield (t ha^{-1}), days to 50% flowering, days to maturity, SPAD chlorophyll meter reading (SCMR) and relative water content (%). Crosses involving these parents might produce heterotic hybrids with high mean performance for the respective traits (Table 2).

Among the lines, ICMB 98222 exhibited desirable significant *gca* effects for nine characters *viz*., number of productive tillers plant^{-1}, plant height (cm), panicle girth

Table 1. Pooled analysis of variance for combining ability for grain yield, morpho-physiological and nutritional traits over four seasons

Source of variation	df	Mean sum of squares							
		DF	DM	PT	PH	PL	PG	TGW	GY
Replications	2	10.82	0.07	0.02	16.00	7.34	0.01	0.21	0.04
Seasons	3	997.08**	1434.75**	39.46**	13431.80**	674.07**	10.78**	166.86**	76.63**
Replications × Seasons	6	4.51	2.97	0.01	5.65	1.62	0.02	0.53	0.04
Hybrids	49	60.67**	73.64**	1.14**	1580.40**	45.67**	0.83**	21.33**	2.99**
Line effect	4	110.53**	58.72**	0.50**	2080.69**	65.22**	1.84**	52.42**	3.63**
Tester effect	9	134.76**	115.67**	0.72**	2290.07**	71.09**	1.78**	17.54**	0.45**
Line × Tester effect	36	36.59**	64.79**	1.31**	1347.39**	37.15**	0.49**	18.82**	2.66**
Seasons × Hybrids	147	8.08**	11.58**	0.43**	163.47**	12.71**	0.07**	2.39**	0.56**
Seasons × Line effect	12	19.24**	11.62**	0.35**	455.13**	36.20**	0.05*	3.44**	0.79**
Seasons × Tester effect	27	6.87**	12.62**	0.55**	121.31**	15.81**	0.09**	2.38**	0.62**
Seasons × LT effect	108	7.14**	11.32**	0.41**	141.57**	9.32**	0.07**	2.28**	0.52**
Error	392	1.22	1.93	0.02	33.58	1.41	0.02	0.40	0.04
Total	599	12.82	17.35	0.41	258.75	11.20	0.15	3.43	0.77

* : Significant at 5% level; ** : Significant at 1% level

DF : Days to 50% flowering; PT : Productive tiller $plant^{-1}$; PL : Panicle length; TGW : 1000 grain weight
DM : Days to maturity; PH : Plant height; PG : Panicle girth; GY : Grain yield

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Table 1. Cont...

Source of variation	df	Mean sum of squares						
		GFY	DFY	SCMR	RWC	HI	Fe	Zn
Replications	2	29.82	0.20	16.26	46.79	5.48	0.60	1.90
Seasons	3	4292.67**	172.83**	666.12**	6681.23**	9016.71**	4488.23**	343.42**
Replications × Seasons	6	6.72	0.06	6.19	26.88	2.96	1.87	1.79
Hybrids	49	256.97**	20.97**	103.95**	749.58**	390.38**	994.78**	490.21**
Line effect	4	1104.94**	31.18**	191.45**	330.44**	477.19**	4416.95**	643.92**
Tester effect	9	434.50**	28.99**	70.52**	884.02**	337.09**	2669.49**	1335.62**
Line × Tester effect	36	118.37**	17.83**	102.58**	762.54**	394.06**	195.86**	261.78**
Seasons × Hybrids	147	29.40**	5.80**	18.68**	50.05**	128.51**	23.11**	24.68**
Seasons × Line effect	12	104.48**	12.80**	30.33**	55.96**	320.35**	38.68	41.44**
Seasons × Tester effect	27	21.45**	4.74	15.12**	32.70**	90.56**	33.13*	19.37**
Seasons × LT effect	108	23.04**	5.29**	18.28**	53.73**	116.69**	18.88**	24.14**
Error	392	3.25	0.45	3.00	9.92	9.36	2.07	1.28
Total	599	52.03	4.30	18.50	113.98	114.81	110.90	48.74

* : Significant at 5% level; ** : Significant at 1% level

GFY : Green fodder yield; SCMR : SPAD chlorophyll meter reading; HI : Harvest index; Zn : Grain Zn content
DFY : Dry fodder yield; RWC : Relative water content; Fe : Grain Fe content

(cm), 1000 grain weight (g), grain yield (t ha^{-1}), SPAD chlorophyll meter reading (SCMR), harvest index (%) and nutritional parameters grain Fe content (ppm) and grain Zn content (ppm). However, the parent ICMR 1809 registered as poor general combing ability effects in desirable direction for all the characters except harvest index (%) (Table 2).

Based on the above discussion, it could be concluded that among the tested 15 parents. The parent *viz*., ICMR 100556 was found to be good general combiner for grain yield and most of the yield characters, earliness and nutritional parameters grain Fe content (ppm) and grain Zn content (ppm). The parent ICMR 13999 was found be the good general combiner for grain yield and most of the yield characters and earliness. As *gca* effects are attributed to additive gene effects, the parents ICMR 100556 and ICMR 13999 might be considered as potential parents for pearl millet improvement programme aimed at yield, earliness and nutritional parameters grain Fe content (ppm) and grain Zn content (ppm).

Specific Combining Ability (*sca*) Effects

Based on the g*ca* effects of the parents involved in specific cross combinations, the hybrids may be grouped into three categories *viz*., good × good, good × poor or poor × good and poor × poor combinations. Most of the hybrids with high and significant *sca* effects did not involve both the parents with good *gca* effects. Contrary to this, hybrids involving parents possessing good *gca* effects did not result in significant *sca* effects in desired direction. The cross combinations with high and significant *sca* effects for more than one yield contributing characters would yield better hybrids. These types of hybrids could be better utilised in population improvement programme *via* recurrent selection so as to isolate superior parents.

Perusal of *sca* effects recorded in the present investigation for 50 hybrids in pooled analysis suggested that none of the cross combinations registered significant *sca* effects in desired direction for all the 15 characters studied. Hence, to decide the *sca* status of a cross, it is necessary to consider the *sca* effects for different characters. ICMB 98222 × ICMR 100584 is best suitable cross for Number of productive tillers plant^{-1}, ICMB 99222 × ICMR 08444 for plant height (cm), ICMB 08666 × ICMR 12555 for panicle length (cm), panicle girth (cm) and grain yield (t ha^{-1}), ICMB 04999 × ICMR 100089 for 1000 grain weight (g), ICMB 04999 × ICMR 100584 for green fodder yield (t ha^{-1}), ICMB 99222 × ICMR 100556 for dry fodder yield^{-1} (t ha^{-1}), ICMB 04999 × ICMR 100549 for days to 50% flowering, ICMB 04999 × ICMR 100549 for days to maturity, ICMB 06111 × ICMR 100556 for SPAD chlorophyll meter readings (60 DAS), ICMB 04999 × ICMR 12555 for Relative water content, ICMB 08666 × ICMR 13999 for Harvest index (%), ICMB 08666 × ICMR 12555 for Grain Fe content (ppm), ICMB 06111 × ICMR 08444 for Grain Zn content (ppm). The top five hybrids in pooled over seasons, *viz*., ICMB 08666 × ICMR 12555, ICMB 99222 × ICMR 100587, ICMB 06111 × ICMR 08444, ICMB 04999 × ICMR 100549 and ICMB 98222 × ICMR 100584 recorded significant positive *sca* effects for grain yield. Among them, the hybrid ICMB 08666 × ICMR 12555 (good × poor) registered desirable and significant *sca* effects in all the four seasons *kharif, late kharif, rabi* and *summer* and pooled over seasons for number of productive tillers plant^{-1}, plant height (cm), panicle length (cm), panicle girth (cm), 1000 grain weight (g), grain yield (t ha^{-1}), days to 50% flowering, days to maturity, SPAD chlorophyll meter reading (SCMR), harvest index and nutritional parameters grain Fe content (ppm) and grain Zn content (ppm); The hybrid ICMB 06111 × ICMR 08444 (poor × poor) recorded significant positive *sca* effects in three seasons *kharif, late kharif* and *summer* for Number of productive tillers plant^{-1}, panicle length (cm), panicle girth (cm), 1000 grain weight (g), grain yield (t ha^{-1}), green fodder yield (t ha^{-1}), dry fodder yield (t ha^{-1}), days to 50% flowering, days to maturity, relative water content (%) and nutritional parameters grain Fe content (ppm) and grain Zn content (ppm) (Table 3).

Hence, these hybrids ICMB 08666 × ICMR 12555 (good × poor) and ICMB 06111 × ICMR 08444 (poor × poor) registered desirable and significant *sca* effects for most of yield components, earliness, SPAD chlorophyll meter reading (SCMR) and nutritional parameters grain Fe content (ppm) and grain Zn content (ppm). Hence these hybrids may be utilized in breeding high yielding hybrids coupled with earliness, drought and nutritional parameters grain Fe content (ppm) and grain Zn content (ppm). The importance of non-additive gene action as documented in this present study is in agreement with the findings of Mungra *et al.* (2015), Badurkar *et al.* (2018), Barathi *et al.* (2020), Anuradha *et al*., (2020), Anusha *et al*., (2021).

Table 2. Estimates of general combining ability effects (*gca*) of lines and testers for grain yield, morpho-physiological and nutritional traits in pooled over seasons

Parent(s)	Days to 50% flowering	Days to maturity	Number of Productive tillers $plant^{-1}$	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	1000 grain weight (g)	Grain yield ($t\ ha^{-1}$)	Green fodder yield ($t\ ha^{-1}$)	Dry fodder yield ($t\ ha^{-1}$)	SPAD chlorophyll meter readings (60 DAS)	Relative water content (%)	Harvest index (%)	Grain Fe content (ppm)	Grain Zn content (ppm)
Lines															
ICMB 98222	-0.97**	-0.43**	0.10**	-1.71**	-0.43**	0.15**	0.59**	0.23**	-1.39**	-0.14*	2.11**	-0.67*	2.49**	5.23**	2.28**
ICMB 99222	0.89**	0.35**	-0.05**	-3.56**	-0.17	0.02	0.25**	-0.08**	-1.85**	0.37**	-1.31**	-1.69**	-2.31**	7.70**	0.94**
ICMB 08666	1.08**	0.42**	0.05**	7.20**	-0.83**	-0.04**	-0.09	0.09**	3.62**	0.56**	-0.25	2.33**	-1.77**	-2.80**	-0.73**
ICMB 04999	-0.13	0.67**	0.01	-0.97	0.38**	-0.18**	0.341**	-0.01	2.83**	-0.02	-0.28	1.08**	0.77**	-5.89**	-3.67**
ICMB 06111	-0.82**	-1.01**	-0.01	-0.97	1.06**	0.05**	-1.10**	-0.23**	-3.22**	-0.76**	-0.26	-1.05**	0.82**	-4.24**	1.18**
Testers															
ICMR 08444	0.02	0.32	0.03	3.85**	1.49**	-0.30**	-0.70**	-0.24**	-0.71**	0.38**	-1.65**	1.88**	-3.67**	-6.61**	-0.50**
ICMR 13999	1.59**	1.01**	0.04*	5.70**	1.96**	0.09**	1.04**	0.39**	3.02**	0.80**	0.57*	3.94**	0.65	-8.09**	-5.67**
ICMR 12555	-3.49**	-3.32**	0.10**	-3.52**	0.38*	-0.05**	-0.41**	-0.34**	-1.18**	-0.86**	0.21	-8.47**	-0.55	8.64**	6.59**
ICMR 100087	-0.56**	-0.88**	-0.04*	-10.90**	-0.33*	-0.12**	0.10	0.09**	-5.43**	-0.66**	0.60**	2.97**	2.83**	-6.23**	-0.22
ICMR 1809	-0.36*	-0.09	-0.02	-6.75**	-1.14**	-0.05**	0.10	-0.05*	-1.62**	-0.72**	-1.00**	0.38	2.82**	-3.17**	-8.95**
ICMR 100089	-0.56**	-0.20	-0.17**	-5.75**	-1.63**	-0.14**	-0.18	0.30**	1.89**	0.19*	1.65**	-0.10*	1.94**	-6.06**	-2.67**
ICMR 100549	-0.04	0.25	0.12**	2.23**	0.16	0.25**	0.59**	0.03	1.22**	1.02**	-0.26	0.92*	-2.20**	2.91**	2.23**
ICMR 100556	0.97**	1.25**	0.10**	5.93**	-0.06	0.24**	0.20	0.22**	1.86**	-0.10	1.31**	1.48**	2.00**	4.56**	3.38**
ICMR 100584	0.57**	0.01	0.04*	3.25**	-0.46**	0.05**	-0.70**	-0.35**	-2.08**	-0.65**	-1.25**	2.58**	-1.46**	8.20**	1.48**
ICMR 100587	1.86**	1.65**	-0.19**	5.96**	-0.37*	0.04*	-0.51**	-0.04	3.03**	0.60**	-0.18	-4.70**	-2.35**	5.86**	4.32**
S.E (g_i) Lines	**0.10**	**0.13**	**0.01**	**0.53**	**0.11**	**0.01**	**0.06**	**0.02**	**0.16**	**0.06**	**0.16**	**0.29**	**0.28**	**0.13**	**0.10**
S.E(g_i) Testers	**0.14**	**0.18**	**0.02**	**0.75**	**0.15**	**0.02**	**0.08**	**0.02**	**0.23**	**0.09**	**0.22**	**0.41**	**0.40**	**0.19**	**0.14**

* : Significant at 5% level; ** : Significant at 1% level

Table 3. Estimates of specific combining ability effects of 50 hybrids for grain yield, morpho-physiological and nutritional traits in pooled over seasons

Hybrid (s)	Days to maturity	Days to 50% flowering	Number of productive tillers plant^{-1}	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	1000 grain weight (g)	Grain yield (t ha^{-1})
ICMB 98222 × ICMR 08444	2.02**	0.72*	-0.05	4.07*	-0.13	-0.04	-0.17	0.23**
ICMB 98222 × ICMR 13999	-0.55	-1.10**	0.11 *	-8.38**	0.94**	0.19**	0.63**	0.22**
ICMB 98222 × ICMR 12555	0.47	0.48	-0.18 **	-16.64**	-3.18**	-0.226**	-1.87**	-0.33**
ICMB 98222 × ICMR 100087	-3.91**	-3.11**	-0.21**	-2.42	0.08	0.13**	0.34	-0.29**
ICMB 98222 × ICMR 1809	-3.43**	-2.23**	-0.42**	-10.72**	-0.74*	0.02	-1.13**	0.16**
ICMB 98222 × ICMR 100089	0.06	-0.45	0.03	4.63**	1.07**	-0.07	0.49**	-0.27**
ICMB 98222 × ICMR 100549	3.45**	1.20**	-0.29**	1.50	-2.11**	-0.18**	-0.89**	-0.20**
ICMB 98222 × ICMR 100556	0.32	0.18	0.32**	0.78	2.15**	0.07	1.45**	0.27**
ICMB 98222 × ICMR 100584	-1.31**	1.58**	0.68**	10.70**	2.71**	0.02	1.86**	0.60**
ICMB 98222 × ICMR 100587	2.88**	2.72**	0.02	16.48**	-0.79*	0.09*	-0.69**	-0.38**
ICMB 99222 × ICMR 08444	2.13**	0.36	0.22**	19.70**	0.76*	-0.12**	0.21	0.01
ICMB 99222 × ICMR 13999	-0.52	0.13	-0.21**	14.59**	-0.13	0.28**	-1.21**	-0.82**
ICMB 99222 × ICMR 12555	-1.16**	-0.29	0.11*	4.52**	-1.61**	-0.17**	-0.81**	-0.69**
ICMB 99222 × ICMR 100087	-0.41	-0.56	0.16**	3.25	0.80*	0.10*	0.52**	0.22**
ICMB 99222× ICMR 1809	-0.04	0.41	-0.12**	3.35*	0.30	0.05	0.36*	-0.23**
ICMB 99222 × ICMR 100089	-0.09	2.28**	0.30**	-13.48**	-0.65	-0.13**	-0.60**	0.11*
ICMB 99222 × ICMR 100549	2.26**	1.68**	0.31**	-10.02**	1.38**	-0.04	0.77**	0.55**
ICMB 99222 × ICMR 100556	-1.51**	-1.76**	-0.48**	-8.35**	-1.71**	0.04	-0.95**	0.11*
ICMB 99222 × ICMR 100584	-0.11	-0.69*	-0.32**	-6.26**	-1.55**	-0.16**	-0.21	-0.01
ICMB 99222 × ICMR 100587	-0.53	-1.56**	0.02	-7.28**	2.40**	0.15**	1.92**	0.74**
ICMB 08666 × ICMR 08444	-2.13**	-0.16	0.02	-8.10**	-0.57	0.08*	1.01**	-0.39**
ICMB 08666 × ICMR 13999	0.76	1.02**	0.24**	10.15**	0.70*	-0.16**	0.67**	0.43**
ICMB 08666 × ICMR 12555	-2.93**	-2.15**	0.66**	13.21**	5.08**	0.45**	2.34**	0.86**
ICMB 08666 × ICMR 100087	2.65**	2.25**	-0.01	10.18**	0.51	0.00	-0.78**	0.21**
ICMB 08666 × ICMR 1809	2.28**	0.97**	-0.18**	1.41	-0.55	0.10*	1.13**	0.26**

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Table 3. Cont...

Hybrid (s)	Days to maturity	Days to 50% flowering	Number of productive tillers plant^{-1}	Plant height (cm)	Panicle length (cm)	Panicle girth (cm)	1000 grain weight (g)	Grain yield (t ha^{-1})
ICMB 08666 × ICMR 100089	-2.16**	-1.50**	0.10*	4.81**	-0.82*	0.01	-1.91**	-0.28**
ICMB 08666 × ICMR 100549	1.08**	1.15**	-0.47**	-7.19**	-1.64**	-0.05	-1.27**	-0.69**
ICMB 08666 × ICMR 100556	-0.11	0.13	-0.05	-7.10**	-0.81*	-0.23**	-0.97**	-0.51**
ICMB 08666 × ICMR 100584	0.06	-0.96**	-0.23**	-2.02	-1.07**	-0.07	0.05	-0.19**
ICMB 08666 × ICMR 100587	0.51	-0.75*	-0.08	-15.35**	-0.82*	-0.13**	-0.27	0.29**
ICMB 04999 × ICMR 08444	0.86*	0.29	-0.29**	-3.90*	-0.75*	-0.13**	-1.53**	-0.52**
ICMB 04999 × ICMR 13999	-0.85*	-1.27**	0.11*	-9.75**	-2.24**	-0.36**	-1.28**	-0.24**
ICMB 04999 × ICMR 12555	3.84**	2.14**	-0.45**	-6.33**	-1.29**	-0.14**	-0.62**	0.16**
ICMB 04999 × ICMR 100087	1.40**	1.21**	0.10*	4.86**	-1.04**	-0.13**	-0.70**	-0.04
ICMB 04999 × ICMR 1809	0.24	1.09**	0.24**	3.28	0.66	0.01	0.60**	0.18**
ICMB 04999 × ICMR 100089	1.72**	0.21	-0.05	1.28	0.77*	0.28**	2.38**	0.37**
ICMB 04999 × ICMR 100549	-6.81**	-5.22**	0.67**	14.97**	4.02**	0.44**	1.75**	0.65**
ICMB 04999 × ICMR 100556	-0.95*	-0.49	0.06	-2.23	0.41	0.23**	0.80**	0.47**
ICMB 04999 × ICMR 100584	0.45	0.99**	-0.27**	-0.51	-0.09	0.07	-0.82**	-0.45**
ICMB 04999 × ICMR 100587	0.11	1.04**	-0.11*	-1.68	-0.46	-0.26**	-0.58**	-0.58**
ICMB 06111 × ICMR 08444	-2.87**	-1.21**	0.10*	-11.77**	0.70*	0.21**	0.49**	0.67**
ICMB 06111 × ICMR 13999	1.17**	1.23**	-0.25**	-6.61**	0.72*	0.05	1.19**	0.41**
ICMB 06111 × ICMR 12555	-0.22	-0.19	-0.14**	5.22**	1.01**	0.09*	0.95**	-0.00
ICMB 06111 × ICMR 100087	0.28	0.21	-0.02	-15.87**	-0.36	-0.09*	0.62**	-0.10
ICMB 06111 × ICMR 1809	0.96*	-0.24	0.49**	2.68	0.33	-0.18**	-0.95**	-0.38**
ICMB 06111 × ICMR 100089	0.48	-0.54	-0.39**	2.75	-0.36	-0.09*	-0.36*	0.08
ICMB 06111 × ICMR 100549	0.01	1.19**	-0.22**	0.75	-6.48**	-0.16**	-0.36*	-0.31**
ICMB 06111 × ICMR 100556	2.26**	1.93**	0.15**	16.89**	-0.04	-0.12**	-0.32	-0.33**
ICMB 06111 × ICMR 100584	0.91*	-0.92**	0.14**	-1.90	-0.00	0.14**	-0.88**	-0.04
ICMB 06111 × ICMR 100587	-2.98**	-1.46**	0.14**	7.84**	-0.34	0.15**	-0.37*	-0.08
S.E (S_{ij})	**0.32**	**0.40**	**0.04**	**1.67**	**0.34**	**0.04**	**0.18**	**0.05**
S.E (S_{ij}-S_{ik})	**0.45**	**0.57**	**0.06**	**2.36**	**0.48**	**0.06**	**0.26**	**0.08**
S.E (S_{ij}-S_{kl})	**0.35**	**0.43**	**0.05**	**1.83**	**0.38**	**0.04**	**0.20**	**0.06**

Cont...

Table 3. Cont...

Hybrid (s)	Green fodder yield (t ha^{-1})	Dry fodder yield (t ha^{-1})	SPAD chlorophyll meter readings (60 DAS)	Relative water content (%)	Harvest index (%)	Grain Fe content (ppm)	Grain Zn content (ppm)
ICMB 98222 × ICMR 08444	-3.36**	-1.85**	-2.70**	-0.56	8.99**	-2.24**	-2.59**
ICMB 98222 × ICMR 13999	3.82**	1.77**	-2.89**	3.04**	-5.93**	0.82*	2.57**
ICMB 98222 × ICMR 12555	-3.17**	-1.79**	-1.01*	-9.46**	6.47**	2.29**	-1.70**
ICMB 98222 × ICMR 100087	-0.93	-1.03**	-2.17**	4.43**	1.79*	5.10**	-5.38**
ICMB 98222 × ICMR 1809	1.98**	0.44*	2.17**	5.51**	-0.75	-2.59**	3.60**
ICMB 98222 × ICMR 100089	-1.93**	1.19**	1.01*	-16.10**	-7.06**	1.01*	-0.93**
ICMB 98222 × ICMR 100549	0.85	0.12	1.21*	5.40**	-3.59**	-4.98**	-0.58
ICMB 98222 × ICMR 100556	-3.08**	-0.88**	-0.30	5.58**	4.56**	-0.90*	-0.98**
ICMB 98222 × ICMR 100584	2.46**	1.15**	-0.82	6.48**	2.18*	-1.12**	2.17**
ICMB 98222 × ICMR 100587	3.34**	0.88**	5.42**	-4.31**	-6.67**	2.61**	3.83**
ICMB 99222 × ICMR 08444	0.60	-0.46*	3.54**	-4.21**	1.68	-3.02**	-8.24**
ICMB 99222 × ICMR 13999	2.07**	0.97**	-0.29	-6.43**	-9.42**	-0.15	3.66**
ICMB 99222 × ICMR 12555	-1.11*	-0.15	-3.79**	-8.69**	-6.73**	-4.48**	0.16
ICMB 99222 × ICMR 100087	-1.20*	-0.88**	3.66**	2.871**	5.17**	-3.84**	-2.29**
ICMB 99222× ICMR 1809	0.82	-0.13	-2.78**	8.71**	-2.68**	-2.23**	2.02**
ICMB 99222 × ICMR 100089	-1.57**	-0.55**	0.95	2.17*	3.05**	-1.12**	-2.09**
ICMB 99222 × ICMR 100549	1.27*	1.13**	-0.65	4.42**	1.01	6.29**	1.26**
ICMB 99222 × ICMR 100556	2.82**	1.956**	-0.40	-2.39**	-5.31**	6.21**	-0.88**
ICMB 99222 × ICMR 100584	-6.67**	-1.95**	-0.63	-7.66**	8.67**	5.30**	4.51**
ICMB 99222 × ICMR 100587	2.96**	0.05	0.39	11.21**	4.54**	-2.96**	1.87**
ICMB 08666 × ICMR 08444	0.38	1.48**	1.88**	-4.40**	-6.16**	-1.10**	8.89**
ICMB 08666 × ICMR 13999	-1.05*	-2.38**	-1.26*	1.12	12.12**	-5.93**	-4.17**
ICMB 08666 × ICMR 12555	0.29	-0.15	4.99**	0.95	5.44**	7.80**	2.60**
ICMB 08666 × ICMR 100087	-3.14**	0.09	0.84	-2.71**	1.76*	-1.83**	4.05**
ICMB 08666 × ICMR 1809	1.47**	-0.23	0.68	2.02*	2.54**	0.42	-1.13**

Cont...

Table 3. Cont...

Hybrid (s)	Green fodder yield (t ha^{-1})	Dry fodder yield (t ha^{-1})	SPAD chlorophyll meter readings (60 DAS)	Relative water content (%)	Harvest index (%)	Grain Fe content (ppm)	Grain Zn content (ppm)
ICMB 08666 × ICMR 100089	1.98**	-0.52**	-3.43**	5.51**	-0.66	0.32	-3.92**
ICMB 08666 × ICMR 100549	2.45**	-0.33	-3.76**	-9.35**	-5.94**	3.81**	1.68**
ICMB 08666 × ICMR 100556	-3.61**	-0.55**	-1.12*	-1.41	-2.09*	0.07	1.71**
ICMB 08666 × ICMR 100584	0.51	1.48**	0.45	0.84	-6.67**	-3.74**	-10.81**
ICMB 08666 × ICMR 100587	0.71	1.12**	0.73	7.43**	-0.34	0.16	1.09**
ICMB 04999 × ICMR 08444	-1.92**	-0.69**	-3.30**	3.60**	-4.11**	3.90**	-7.39**
ICMB 04999 × ICMR 13999	-5.54**	-0.27	4.83**	-0.90	-0.90	1.41**	1.02**
ICMB 04999 × ICMR 12555	0.72	0.97**	-0.15	13.70**	-1.95*	-7.04**	2.76**
ICMB 04999 × ICMR 100087	3.90**	0.65**	-0.79	-0.07	-2.69**	-1.19**	-1.68**
ICMB 04999 × ICMR 1809	-0.55	0.49*	1.83**	1.77	2.50**	3.52**	-2.95**
ICMB 04999 × ICMR 100089	1.89**	-0.01	0.64	3.82**	3.55**	-2.60**	5.52**
ICMB 04999 × ICMR 100549	-1.27*	0.94**	4.81**	-1.77	5.16**	-4.43**	2.61**
ICMB 04999 × ICMR 100556	2.44**	-0.43*	-3.68**	1.09	6.45**	0.49	2.22**
ICMB 04999 × ICMR 100584	4.92**	-0.14	-0.29	-0.68	-6.49**	1.93**	2.37**
ICMB 04999 × ICMR 100587	-4.60**	-1.51**	-3.91*	-20.56**	-1.51	3.11**	-4.47**
ICMB 06111 × ICMR 08444	4.29**	1.52**	0.57	5.57**	-0.40	2.46**	9.34**
ICMB 06111 × ICMR 13999	0.69	-0.10	-0.39	3.17**	4.14**	3.85**	-3.08**
ICMB 06111 × ICMR 12555	3.26**	1.12**	-0.04	3.50**	-3.23**	1.42**	-3.84**
ICMB 06111 × ICMR 100087	1.37**	1.17**	-1.54**	-4.52**	-6.03**	1.77**	5.30**
ICMB 06111 × ICMR 1809	-3.72**	-0.56**	-1.90**	-18.02**	-1.61	0.87*	-1.55**
ICMB 06111 × ICMR 100089	-0.37	-0.11	0.82	4.61**	1.11	2.38**	1.42**
ICMB 06111 × ICMR 100549	-3.32**	-1.86**	-1.68**	1.30	3.36**	-0.69	-4.98**
ICMB 06111 × ICMR 100556	1.43**	-0.09	5.51**	-2.87**	-3.62**	-5.87**	-2.07**
ICMB 06111 × ICMR 100584	-1.22*	-0.54**	1.28*	1.02	2.31**	-2.38**	1.77**
ICMB 06111 × ICMR 100587	-2.41**	-0.54**	-2.63**	6.23**	3.97**	-3.82**	-2.32**
S.E (S_{ij})	**0.52**	**0.19**	**0.50**	**0.91**	**0.88**	**0.41**	**0.33**
S.E (S_{ij}-S_{ik})	**0.73**	**0.27**	**0.70**	**1.29**	**1.25**	**0.59**	**0.46**
S.E (S_{ij}-S_{kl})	**0.57**	**0.21**	**0.55**	**1.00**	**0.97**	**0.45**	**0.36**

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PERFORMANCE OF CHICKPEA (*Cicer arietinum* L.) UNDER DIFFERENT SOWING BED METHODS AND IRRIGATION LEVELS

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ABSTRACT

A field experiment was conducted to study the growth and yield of chickpea (*Cicer arietinum* L.) under different sowing beds, on sandy loam soils at College Farm, Agricultural College, Mahanandi campus of Acharya N.G. Ranga Agricultural University during *rabi*, 2021-2022. The experiment was laid out in split-plot design with nine treatments and replicated thrice. The results revealed that sowing beds didn't show any significant influence on plant height, 100 seed weight, haulm yield and harvest index. Significantly higher number of branches and dry matter production was registered with broad bed and furrow with paired rows than flat bed and ridge and furrow. Broad bed & furrow with paired rows recorded significantly greater number of pods per plant and seed yield than flatbed and was at par with ridge and furrow. Two irrigations each at 30 and 50 DAS found significant influence on plant height and number of branches plant^{-1}, dry matter production, number of pods plant^{-1}, seed yield and haulm yield than one irrigation at 30 DAS and rainfed.

KEYWORDS: Chickpea, sowing beds, irrigation levels, *rabi*, yield.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is an important *rabi* pulse crop grown in India for its economic importance besides maintaining soil fertility and often known as "king of pulses". In general chickpea is known as gram or Bengal-gram. In India, chickpea is cultivated an area of 9.69 million hectares with a production of 11.07 million tonnes and with a productivity of 1142 kg ha^{-1} (Anonymous, 2021a). In Andhra Pradesh, it is cultivated in an area of 0.45 million hectares with a production of 0.55 million tonnes and with a productivity of 1218 kg ha^{-1} (Anonymous, 2021b).

Chickpea is generally cultivated as rainfed sole crop and many times it experiences moisture stress during its growth stages that results in low productivity. Many times, the crop is also damaged due to either heavy rainfall or improper irrigation.

Modified land configuration such as furrow irrigated raised bed has shown good promise in enhancing chickpea performance and water productivity (Jat *et al.,* 2005). Raised bed planting prevented excess moisture problem in heavy soils. Chickpea is very sensitive to water logging condition and flatbed sowing results in heavy plant mortality. Sowing the Bengal gram crop on raised bed and ridge and furrow method was found to be advantageous compared to flatbed method of sowing (Ravindra *et al*., 2016).

Maintenance of optimum plant population is important parameter for enhancing productivity of Bengal gram. Changes in plant geometry and plant population per unit area due to different planting layouts leads to different pattern for utilization of growth resources viz., nutrients, moisture, radiation energy and space. Pairing of rows were more productive than conventional single-row system. Sowing in paired-row has been found advantageous in many rainfed crops. Better root dry weight, greater intercepted photosynthetically active radiation, high leaf photosynthesis and high nutrient uptake are noticed under paired-row than traditional flat-bed method (Mandal *et al*., 2019). Change in crop geometry keeping the seed rate same is a non-monetary input, that fetches additional yields (Mandal *et al*., 2019). Hence, the present experiment was proposed to find out the performance of chickpea (*Cicer arietinum* L.) under different irrigation regimes and sowing beds.

MATERIAL AND METHODS

A field trail was carried out at Agricultural College Farm, Mahanadi campus of Acharya N.G. Ranga Agricultural University during *rabi* 2021-2022. The design adopted was split-plot design and replicated thrice. The main plots consisted of three types of sowing beds *viz.,* Flat bed (45 cm × 10 cm) (P_1), Ridge and furrow (45 cm × 10 cm) (P_2) and broad bed and furrow in paired rows (60-30 × 10 cm) (P_3) assigned to main plots and irrigation levels *viz.,* rainfed (I_1), one irrigation

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Table 1. Plant height, number of branches plant^{-1}, dry matter accumulation in chickpea as influenced by different sowing bed methods and irrigation levels

Treatments	Plant height (cm)	Number of branches plant^{-1}	Dry matter production (kg ha^{-1})
Sowing beds			
P_1 : Flat-bed (45 cm × 10 cm)	38.3	15.6	721
P_2 : Ridge and furrow (45 cm × 10 cm)	37.4	18.0	1085
P_3 : Broad bed and furrow with paired rows (60-30 cm × 10 cm)	39.8	21.3	1373
SEm+	**1.14**	**0.61**	**44.70**
CD (P=0.05)	**NS**	**2.410**	**175.510**
Irrigation levels			
I_1 : Rainfed	36.3	16.6	801
I_2 : One irrigation at 30 DAS	37.8	18.5	1083
I_3 : Two irrigations each at 30 and 50 DAS	41.4	19.8	1295
SEm+	**0.57**	**0.84**	**33.76**
CD (P=0.05)	**1.76**	**2.59**	**104.03**

of 30 mm depth at 30 DAS (I_2) and two irrigations each of 30 mm depth at 30 and 50 DAS (I_3) were allotted to sub plots.

The soil of the experimental field was sandy loam in texture, with neutral in reaction (pH 7.33), low in organic carbon (0.49%), available nitrogen (258 kg ha^{-1}) and available phosphorus (49 kg ha^{-1}) and high in available potassium (584 kg ha^{-1}). Diammonium phosphate (DAP) was applied to the experimental plots @ 125 kg ha^{-1} as basal to supply N and P_2O_5 required as per the recommendation. The chickpea variety NBeG-49 having duration of 90-105 days was taken as test variety. The row to row spacing was taken as 45 cm in flatbed and ridge and furrow sowing bed. The spacing adapted for broad bed and furrow was 60 cm between paired rows. The spacing was 60 cm between pairs and 30 cm between paired rows. Plant to plant spacing was 10 cm and gap filling was done at 10 DAS. Pre-emergence application of pendimethalin 1.0 kg ha^{-1} was sprayed one day after sowing. Observations on plant height, number of branches plant^{-1}, dry matter accumulation, number of pods plant^{-1}, 100 seed weight, seed yield, haulm yield and harvest index were recorded by following standard procedure. The critical difference was correlated at 5 per cent level of significance to compare different treatment means as suggested by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Growth parameters

The growth parameters in chickpea were influenced by different sowing bed methods. The sowing beds didn't show any significant influence on plant height. But the tall plants were recorded in broad bed and furrow with paired rows than flatbed and ridge and furrows. Significantly higher number of branches were registered with broad bed and furrow with paired rows than flatbed and ridge and furrow. These results are in line with the findings of Archana *et al*. (2021) and Tomar *et al*. (2020). Higher dry matter production registered with broad bed and furrow with paired rows than flatbed and ridge and furrow (Table 1). These results are in line with findings of Bharade *et al*. (2019) and Baraker *et al*. (2017). It might be due to better soil structure and maintenance of air-water regime as well as good supply of nutrients and water in the root zone of crop, availability of wider spacing, the plant get sufficient space above the ground and below the ground grow as well as increased light

Table 2. Yield attributes and yield parameters of chickpea as influenced by different sowing bed methods and irrigation levels

Treatments	No. of pods plant^{-1}	100 seed weight (g)	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index (%)
Sowing beds					
P_1 : Flat-bed (45 cm × 10 cm)	34.1	30.1	957	1000	49.5
P_2 : Ridge and furrow (45 cm × 10 cm)	37.6	30.4	1083	1071	50.2
P_3 : Broad bed and furrow with paired rows (60-30 cm × 10 cm)	44.2	30.4	1168	1074	51.3
SEm+	1.86	0.37	53.07	30.39	1.13
CD (P=0.05)	7.31	NS	208.39	NS	NS
Irrigation levels					
I_1 : Rainfed	32.8	29.8	845	844	49.3
I_2 : One irrigation at 30 DAS	38.9	30.4	1041	1047	50.3
I_3 : Two irrigations each at 30 and 50 DAS	44.0	30.7	1322	1253	51.4
SEm+	**1.80**	**0.35**	**29.14**	**52.10**	**1.12**
CD (P=0.05)	**5.53**	**NS**	**89.78**	**160.54**	**NS**

transmission in the canopy, leading to greater vegetative growth which enable high foliage. The irrigation levels found significant effect on growth parameters. Two irrigations each at 30 & 50 DAS found significant influence on plant height and number of branches per plant and dry matter production than One irrigation at 30 DAS and rainfed (Table 1). These results are in line with the findings of Ravindra *et al*. (2016) and Narendra *et al*. (2015).

Yield attributes

Maximum number of pods plant^{-1} were recorded in broad bed and furrow with paired row as compared to flatbed and was on par with ridge and furrow (Table 2). It might be due to better root development, greater intercepted photosynthetically active radiation, rate of leaf photosynthesis in turn gave high number of branches, dry matter production, more number of flowers contributed to higher number of pods per plant. These findings were in accordance with the results of Mandal *et al*. (2019) and Joshi *et al*. (2018). The effect of sowing beds and irrigation levels on 100 seed weight (g) found non-significant (Table 2). Two irrigations each at 30 & 50 DAS found significant influence on yield attributes like number of pods per plant than One irrigation at 30 DAS and rainfed (Table 2). These findings were in accordance with the results of Kemal *et al*. (2018) and Patel *et al*. (2016).

Yields

Significantly highest seed yield (kg ha^{-1}) was recorded with broad bed and furrow with paired rows than flatbed and was at par with ridge and furrow (Table 2). It might be due to more number of branches and good aeration, good drainage and mobilisation of nutrients intensified. The similar findings are in agreement with the results of Shaikh *et al*. (2019) and Joshi *et al*. (2018). The sowing beds didn't show any significant influence on haulm yield. The high haulm yield was recorded with broad bed & furrow with paired rows than flatbed and ridge and furrow (Table 2). Irrigation levels found significant effect on seed and haulm yield. Two irrigations each at 30 and 50 DAS found superior yields than one irrigation at 30 DAS and rainfed conditions. The similar findings in line with Ravindra *et al*. (2016) and Narendra *et. al*. (2015). The response of sowing beds and irrigation levels on harvest index was found to be non-significant.

The broad bed and furrow in paired rows (60-30 × 10 cm) (P_3) and two irrigations each at 30 and 50 DAS (I_3) recorded higher plant height, greater number of branches, dry matter production, number of seeds per plant, maximum seed yield, haulm yield and harvest index as compared to other treatments. Hence, broad bed and furrow in paired rows (60-30 × 10 cm) (P_3) and two irrigations each at 30 and 50 DAS (I_3) was found superior in recording higher growth parameters and yields of chickpea.

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PROFILE OF MEMBERS OF THE TRIBAL FARMER PRODUCER GROUPS (FPGs) IN VISAKHAPATNAM DISTRICT OF ANDHRA PRADESH

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ABSTRACT

The present study was carried out to know the profile of the members of the tribal FPGs in Visakhapatnam district of Andhra Pradesh over a randomly drawn sample of 120 respondents. The results revealed that majority of the members of tribal FPGs were in middle age (71.67%), completed primary school education (36.66%), had combined occupations - agriculture + livestock + wage work + non timber forest products (50.00%) and had small land holding (49.16%). The other variables like annual income (64.17%), farming experience (66.67%), training undergone (60.00%), mass media exposure (73.33%), extension contact (74.17%), social participation (60.83%), scientific orientation (56.67%), innovativeness (61.67%), economic orientation (58.34%), achievement motivation (64.17%) and marketing strategies (54.17%) were found to be medium level.

KEYWORDS: Farmer Producer Groups (FPGs), Profile, tribal.

INTRODUCTION

India has one of the largest concentrations of tribal population in the world. Tribals live in about 15 per cent of the country's areas, in various ecological and geo climatic conditions ranging from plains, forests, hills and inaccessible areas. In spite of favourable resource conditions, tribal regions perform poorly in terms of infrastructure, returns from agriculture and almost all human development indicators. Tribes are blessed with ample of opportunities like forest resources for improving their livelihood but they are facing problems in getting quality inputs and good price for their produce due to geographical location. The challenges faced by the small and marginal tribal farmers are being attempted to solve through the concept of group approach that empowers them by economies of scale and access to information, agricultural services, technology, etc. SHGs, FIGs, Co-operatives, producers associations, marketing associations, etc., had bestowed in maximizing the input-output ratio and finally increasing the profit of producers. Aggregating producers into collectives is now universally accepted as one of the most effective means of reducing the risk in agriculture and improving the access of small and marginal producers to investments, technology and markets. Farmer producer organization came to an existence in India during the year 2002, by the recommendation of Y.K. Alagh and first implemented in Madhya Pradesh as District Poverty Innovative Project (DPIP) under RKVY.

Mobilizing farmers into groups of between 15-20 members at the village level called Farmer Producer Groups (FPGs) and building up their associations to an appropriate federating point *i.e.* FPOs. Farmer producer Groups have become a widespread, essential and effective tool for empowering the under privileged communities. FPGs being a collective platform for small and marginal farmers provide backward linkage to timely availability and access to quality inputs at affordable prices and a forward linkage to effective credit and marketing sources, increased contribution towards enhancing income which determine the success of the group approach. FPG is an innovative approach with an idea to develop a value chain for the produces, establish brand value and link the farmers with markets and consumers. The main objective of the study was to find out the profile of members of the tribal FPGs in Visakhapatnam district.

MATERIAL AND METHODS

The study was conducted with an *Ex post facto* research design to analyse the profile of members of the tribal FPGs in Visakhapatnam district of Andhra Pradesh. Visakhapatnam district was purposively selected for the study since it is having highest number of tribal farmers in Andhra Pradesh state. Araku valley mandal and Dumbriguda mandals were selected randomly from a total of 11 tribal mandals in Visakhapatnam district.

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From each of the selected two mandals, 12 Farmer Producer Groups (FPGs) were selected randomly, thus making a total of 24 FPGs. From each of the selected 24 FPGs, five members were selected by following simple random sampling method, thus making a total of 120 respondents as the sample of the study. The data was collected through a structured comprehensive interview schedule and analysed using arithmetic mean, standard deviation, frequencies and percentage for drawing meaningful interpretations.

RESULTS AND DISCUSSION

The members of tribal FPGs were distributed into different categories based on their selected profile characteristics and the results were presented in the Table 1.

Age

More than two third (71.67%) of members of tribal FPGs belonged to middle age category followed by old age (18.33%) and young age (10.00%) categories. The probable reason might be due to the reason that the old age and middle age tribal FPG farmers might be continuing their life in the tribal environment by taking different tribal livelihood options. On the other side the young generation were not interested in farming and they might have undergone higher education and moved to plains for employment and other occupational avenues. The findings of the present study were similar with the studies of Tudu *et al*. (2013) and Mareeswaran (2014).

Education

About 36.66 per cent of the members of tribal FPGs were educated up to primary school followed by high school (23.34%), middle school (20.84%), illiterate (10.00%) and functionally literate (9.16%) level of education. None of the respondents had college level of education. The probable reasons for the most of tribal farmers being educated upto primary level might be that instead of going to school during their childhood they were involved in farming activities as it was the only source for survival of their family. Besides, they were not aware about importance of education and also lack of enough formal educational institutions beyond primary level in the region might be the another reasons. The same results were presented by Dipika and Sharma (2010) and Upadhyay *et al.* (2020).

Occupation

About half (50.00%) of the members of tribal FPGs get their living based on the combination of occupations like farming, rearing of livestock, collection of non timber forest products and wage work. About 18.34 per cent of the members of FPGs were involved in the business besides the above activities. In the past, before joining as FPG members the livelihood of tribal FPG members was dependent solely upon cultivation, animal husbandry and sale of forest produce. But after joining as FPG members, situation changed.

The data showed diverse occupational activities of the tribal farmers. For tribals, agriculture and collection of non timber forest produce is a common practice to eke out living and make some money. Besides, they also work in the forests and nearby villages in developmental works like laying of roads and other works taken up by the Department of Forestry. In addition to this, majority of the members of FPGs built their houses with the income earned from the work done under Government's Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA). The results were in accordance with Kiran (2011).

Annual income

Nearly two third (64.17%) of the members of tribal FPGs had medium income level followed by low level of income (20.83%) and only 15.00 per cent of respondents had high income level. The probable reason might be that the tribal FPG members led their lives under resource poor conditions with limited access to urban culture. The members might also be satisfied with their present standard of living which was far away from the people living in plains. Due to illiteracy and lack of awareness on the tribal developmental programs they might have not been able to identify the sources of getting high income. A very meager amount of tribal farmers who were local leaders and relatively resource rich might be under high income category. The findings of the study were in conformity with the studies of Malik (2010) and Upadhyay *et al*. (2020).

Farm size

Almost half (49.16%) of the members of tribal FPGs possess small land holding followed by marginal land holding (32.50%), semi medium land holding (15.00%), medium land holding (2.50%) and a very few members

Table 1. Distribution of members of tribal FPGs according to their profile characteristics (n = 120)

S. No.	Variables	Category	Members of tribal FPGs Frequency (f)	Percentage (%)
1.	Age	Young age (<35 years)	12	10.00
		Middle age (36-55 years)	86	71.67
		Old age (>56 years)	22	18.33
		Mean	**-**	
		S.D	**-**	
2.	Education	Illiterate	12	10.00
		Functionally literate	11	9.16
		Primary school	44	36.66
		Middle school	28	23.34
		High school	25	20.84
		College level	0	0.00
		Mean	**-**	
		S.D	**-**	
3.	Occupation	Agriculture	3	2.50
		Agriculture + wagework	3	2.50
		Agriculture + livestock	1	0.83
		Agriculture + livestock + wage work	31	25.83
		Agriculture + livestock + wage work + Non timber forest products (NTFP)	60	50.00
		Agriculture + livestock + wage work + Non timber forest products + business	22	18.43
		Mean	**-**	
		S.D	**-**	
4.	Annual income	Low	25	20.83
		Medium	77	64.17
		High	18	15.00
		Mean	**236750**	
		S.D	**75148.73**	
5.	Farm size	Marginal land holding (1ha or less)	39	32.50
		Small land holding (1 to 2 ha)	59	49.16
		Semi-medium land holding (2 to 4ha)	18	15.00
		Medium land holding (4 to 10ha)	3	2.50
		Large land holding (above 10ha)	1	0.84
		Mean	**-**	
		SD	**-**	
6.	Farming experience	Low	25	20.83
		Medium	80	66.67
		High	15	12.50
		Mean	**20.05**	
		S.D	**9.97**	
7.	Training undergone	Low	18	15.00
		Medium	72	60.00
		High	30	25.00
		Mean	**4.57**	
		S.D	**1.30**	

Table 1. Cont... **(n = 120)**

S. No.	Variables	Category	Members of tribal FPGs	
			Frequency (f)	Percentage (%)
8.	Mass media exposure	Low	15	12.50
		Medium	88	73.33
		High	17	14.17
		Mean	**15.30**	
		S.D	**3.04**	
9.	Extension contact	Low	11	9.16
		Medium	89	74.17
		High	20	16.67
		Mean	**49.51**	
		S.D	**3.38**	
10.	Social participation	Low	21	17.50
		Medium	73	60.83
		High	26	21.67
		Mean	**8.81**	
		S.D	**1.23**	
11.	Scientific orientation	Low	30	25.00
		Medium	68	56.67
		High	22	18.33
		Mean	**27.73**	
		S.D	**1.43**	
12.	Innovativeness	Low	18	15.00
		Medium	74	61.67
		High	28	23.33
		Mean	**39.79**	
		S.D	**1.68**	
13.	Economic orientation	Low	22	18.33
		Medium	70	58.34
		High	28	23.33
		Mean	**27.81**	
		S.D	**1.55**	
14.	Achievement Motivation	Low	13	10.83
		Medium	77	64.17
		High	30	25.00
		Mean	**30.75**	
		S.D	**2.78**	
15.	Marketing strategies	Low	25	20.83
		Medium	65	54.17
		High	30	25.00
		Mean	**6.17**	
		S.D	**1.82**	

(0.84%) possess large land holding. The basic orientation of the tribal farmer is towards livelihood rather than commercialization. Hence all the tribal farmers might be taking agriculture on a limited scale mostly for their household requirement. Further, fragmentation of land from one generation to another generation also led to small land holding size by the farmers. On the other side, land restrictions by the Forest Department over tribal farmers and land encroachments by landlords and estate owners in the regions of tribal zones also might have resulted in the small land holdings. These results were in accordance with the findings of Gandhale and Tekale (2021).

Farming experience

Two third (66.67%) of the members of tribal FPGs had medium level of farming experience, followed by low (20.83%) and high (12.50%) levels of farming experience. As agriculture is one of the ancient livelihood options for tribals, the old age tribals might be continuing agriculture from generation to generation. Previously the tribal farmers might have depended purely on forest based livelihood activities. Due to restrictions by the Forest Department on various forest based activities, the tribal farmers might have shifted to agriculture and allied farm activities. On the other side, young tribal farmers might have put up less farming experience due to their education and less farming experience. Hence, the above trend was observed. The results were in confirmation with the findings reported by Senthil (2013).

Training undergone

More than half (60.00%) of the members of tribal FPGs had medium level of training followed by high (25.00%) and low (15.00%) levels of training. The reason might be due to the fact that FPG members attended most of the training programs organized by the promoting and facilitating agencies. As FPG is a new concept, members felt that training is an important component to understand and implement it properly. Few members belonged to high training category, as they knew the importance of training in bringing perfection in any activity undertaken. Some young and enthusiastic farmers participated in training programs regularly organized by the promoting and facilitating agencies. Lack of awareness among few tribal farmers regarding usefulness of training programs, improper planning and organization of training programs on the part of promoting and facilitating agencies, farmers being busy with their farm operations, lack of interest in sparing their time to participate in the training programs were some of the probable reasons for the remaining tribal farmers to be in low category of training. Similar findings were observed with the findings of Rathakrishnan (2017).

Mass media exposure

About 73.33 per cent of the respondents were having medium mass media exposure followed by high (14.17%) and low (12.50%) levels of mass media exposure. The advancement of information and communication technologies even reached tribal peripheries. The mass media technologies like radio, television and mobile were in use in tribal areas. The differences in standard of living, level of education, remoteness of the village might have shown the difference in possession and utilization of different mass media sources by the members of FPGs. Whereas the print media usage was almost nil among the members of FPGs. The research findings were in correspondence with the study of Saha and Bahal (2010).

Extension contact

Majority of the members of tribal FPGs had medium (74.17%) extension contact followed by the rest with high (16.67%) and low (9.16%) levels of extension contact. The probable reason might be due to poor accessibility of tribal villages in terms of bad roads, poor transport and communication facilities, high altitudes, bad weather and inadequate extension staff (reluctancy of extension staff to work in remote areas). Hence, the personnel working at lower levels i.e. from the cadre of Sub- Assistant are to be provided with transport facilities, incentives and agency allowances, so that they could frequently visit the interior areas and build up good rapport with the tribals for successful implementation of development programmes.

Once tribal farmers make good contacts, they will be willing to participate in the programmes organized by the extension personnel. Hence, the onus of developing contacts lies higher on the extension staff in order to bring about desirable changes in the livelihoods of tribal farmers. The findings were in line with the findings of Marbaniang *et al*. (2013).

Social participation

More than half (60.83%) of the respondents had medium level of social participation followed by high (21.67%) and low (17.50%) levels of social participation. The tribal FPG members might be leading their life with more dependence on the environment and its associated members. During the course of action, the FPG members might be trying to associate with the members of VIKASA organization or agencies as members or representatives to realize the benefits of their welfare programs. On the other side, the ignorant and innocent tribal people might have retained as non-members of such welfare programs. Lavanya (2010) reported the similar results.

Scientific orientation

More than half (56.67%) of the members of tribal FPGs had medium scientific orientation followed by the rest with high (25.00%) and low (18.33%) levels of scientific orientation. Tribals are inclined to traditions, religious beliefs and cultures as they live in the interior forests. Tribals are usually having low urban contact and they feel shy to mingle with non-tribals and follow traditional methods of farming with their traditional knowledge which might be the probable reason for medium to low levels of scientific orientation. The other reason might be due to medium to high extension contact and medium mass media exposure which helped them to apply some scientific practices. Similar findings were observed by Kiran (2011) and Senthil (2013).

Innovativeness

About 61.67 per cent of the members of tribal FPGs had medium level of innovativeness followed by high (23.33%) and low (15.00%) levels of innovativeness. The reason might be due to the fact that majority of the tribal FPG members were of middle aged had primary school education, had medium mass media exposure and medium level of extension contact which favored them to atleast try new technologies and were able to update their knowledge and skills time to time and to readily accept the new technologies provided by the FPOs in the farming activities. Besides, the FPG members were receptive to new ideas to learn new ways of farming which resulted in medium innovativeness. Some tribal FPG members were of more traditional type and were mostly illiterates, with low extension contact and low mass media exposure made them unable to reach out for changes towards modern technologies, thus had low innovativeness. Similar finding were reported by Upadhyay *et al*. (2020).

Economic orientation

More than half (58.34%) of the members of tribal FPGs had medium level of economic orientation followed by high (23.33%) and low (18.33%) levels of economic orientation. Economy is the core component of survival, existence and development of any human being. No exception, it is also a major component for tribal life but the orientation might be towards survival and existence than development. Due to their limited income and limited vision towards their future life, they might be relatively less oriented towards their economic development. The variation in this direction among tribals might be due to changes in their education, standard of living and other situational variables. Marbaniang (2010) and Ahire *et al.* (2015) expressed the similar results in their studies.

Achievement motivation

Nearly two third (64.17%) of respondents belonged to medium achievement motivation category followed by high (25.00%) and low (10.83%) achievement motivation categories. The results indicated that medium achievement motivation might be due to reason that most of the respondents were living in poor socio-economic conditions coupled with the illiteracy. The members of tribal FPGs were always striving hard at getting more income working as Agricultural labour and without that they could not survive themselves. Further, their family members also strived hard basically for their food and shelter, but they were regularly failed in meeting their livelihood requirement. Most of the members of FPGs were also small farmers with medium extension contact did not put more efforts to increase the production. Hence, this condition might have resulted in such trend. From the results we can conclude that most of the respondents belonged to medium level of achievement motivation, which made us to give a rethink while developing new, locally suited and feasible technologies so as to motivate the respondents towards high level of achievement motivation. George *et al.* (2012) expressed similar results in their studies.

Marketing strategies

More than half (54.16%) of the members of tribal FPGs had medium marketing strategies followed by high (25.00%) and low (20.83%) marketing strategies. Majority of the members of FPGs have medium marketing strategies due to the fact that the members did not know about the various marketing patterns and marketing opportunities to sell their produce. It was a fact that tribals were not having marketing facilities within their reach and they have to blindly rely on the middlemen in marketing of their produce. Market facilities should be created for a cluster of villages especially in remote areas where transportation facilities were meager. Most of the tribal farmers were not educated and were not aware of the digital marketing. On the other hand the members who were aware of the various platforms for selling their produce by eliminating middle men were having high marketing strategies. The main motto of forming tribal farmers into FPGs was that economies of scale of produce which improved bargaining power of the farmers and free from market intermediaries. Hence, the farmers had strong consciousness about the purpose of FPGs.

The results revealed that majority of the members of tribal FPGs belonged to medium level of profile characteristics. Hence efforts were needed to improve these characters by providing information on different information sources and motivate them to access different sources, organize field exposure visits to successful FPOs, farmer extension functionaries and NGOs in the field of FPOs to improve the personal characters through efficient utilization of capacity building activities and services provided by the FPOs to the members of tribal FPGs.

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SUPPLY CHAIN ANALYSIS OF MAIZE IN RANGAREDDY DISTRICT OF TELANGANA

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ABSTRACT

In Telangana's Rangareddy district, research was conducted to explore the maize supply chain. Six villages were selected for the present study from which sixty farmers and ten market intermediaries were polled to discover more about the maize supply chain's existing routes and their effectiveness for marketing. There were four significant supply chain pathways in the study area. 46.67 per cent of the farmers have chosen supply chain I among the four supply chains. Channel I has the lowest marketing expense per quintal of maize among the four marketing channels, followed by Channel II, Channel III, and Channel IV. The marketing expenses per quintal of maize sold through the above channels were 100.20, 128.04, 231.27 and 259.11 rupees respectively. Acharya's method suggested that channel I (15.21) was efficient than channel II (11.47), channel III (5.38), and channel IV (4.77).

KEYWORDS: Maize, Marketing cost, Marketing efficiency, Supply chain channels

INTRODUCTION

Maize is one of the world's most adaptable crop. It is grown in the tropics, subtropics, and temperate regions up to 500 to 4000 meters above sea level in all semi-arid, irrigated conditions. Maize has a broad range of applications due to its global distribution and lower price. It is used not only for direct human consumption, industrially processed food and livestock feed but also in non-food industrial items such as starches, acids, and alcohols. Recently been a renewed interest in using maize to make ethanol as a substitute for petroleum-based fuels.

As maize has the highest genetic yield potential among the cereals, it is known as the "Queen of Cereals" globally (Balvant and Gangadevi, 2018). With a mean yield of 5.75 MT ha^{-1}, more than 170 countries are currently producing 1147 000 MT of maize on a 193 000 ha field (FAOSTAT, 2020).

In India, maize crop is grown in a wide range of 9200 ha with a yield of 27200 MT (FAOSTAT, 2020). With 3730 MT, Karnataka produces the most maize, followed by Madhya Pradesh and Bihar. The most productive state is Tamil Nadu, with Andhra Pradesh and West Bengal following closely behind it (6551 kg ha^{-1}).The foremost crop produced in Telangana is maize (corn), which is grown on roughly 14 lakh acres and yields 16 lakh tonnes yearly. Siddipet, Nagarkurnool, Rangareddy, Vikarabad, Mehaboobnagar, Kamareddy, Nizamabad, Karimnagar, and Jagtial are notable districts in Telangana for producing maize, responsible for about 85 per cent of the state's total production.

An efficient network of agricultural marketing system is a vital link between farmers and consumers (Jaisridhar *et al.,* 2012). Net price received by the farmers depends on the efficiency of the marketing channel. Hence, the present study was undertaken with the objectives of understanding the existing marketing channels of maize, price spread of maize and examine the efficiency of various supply chains in the study area.

MATERIAL AND METHODS

Area under maize cultivation is being increasing for the past decade due to increase in its usage as poultry feed in Rangareddy district of Telangana and hence, Rangareddy district was purposely selected for the study. Two mandals namely Nandigama and Kothur from Rangareddy district where maize was majorly grown were chosen for the study. Appareddyguda, Cheguru, Majid Mamidpally villages from Nandigama mandal and Kodicherla, Penjerla, Manchanpadu villages from Kothur mandal were selected randomly for the study. Ten farmers from each village were selected randomly, thus the total sample size of farmers constitutes 60 farmers. The primary data was collected from farmers through personal interview method by using a schedule. The primary data pertain to the year 2020-2021. Descriptive analysis in this study was performed by employing tabular analysis technique. The producer's price is the net price received by the farmer at the time of first sale. This

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is equal to the wholesale price at the primary assembling center, minus the charges borne by the framers in selling.

$$P_f = P_A - C_f$$

where,

P_A= is the price received by the farmer

C_f= is the marketing cost incurred by farmer

P_f= is the producer's price

Marketing efficiency

Marketing efficiency for the identified supply chain channels can be measured by using three methods.

a) Conventional Method

Efficiency of any activity or process is defined as the ratio of output to input. If 'O' and 'I' are respectively output and input of the marketing system and 'E' is the index of marketing efficiency, then

$$E = O \div I \times 100$$

A higher value of E denotes higher level of efficiency and vice versa. When applied in the area of marketing, output is the 'value added' by the marketing system and 'input is the real cost of marketing (including some fair margins of intermediaries)'

b) Shepherd Approach

Shepherd suggested that the ratio of the total value of goods marketed to the marketing cost may be used as a measure of marketing efficiency. The higher the ratio, the higher efficiency and vice versa. This method eliminates the problem of measurement of value added.

c) Acharya's approach

This is said to be the efficient method in measuring marketing efficiency. According to Acharya and Agrawal (1992) marketing efficiency is the ratio of net price received by the farmer to the total marketing cost plus total marketing efficiency.

$$MME = FP \div (MC + MM) X 100.$$

where,

MME : Modified measure of marketing efficiency

FP : Price received by the farmer

MC : Total marketing costs

MM : Total marketing margins

Marketing cost and margin

The concurrent margin has been estimated, as it is the difference between the prices prevailing at successive stages of marketing at a given point of time, e.g., the difference between farmers's selling price and retail price on a specific date is the total concurrent margin. To study the existing marketing system, marketing margins and cost for different channels in the selected markets and the price spread was estimated by using the following formulae.

Market Margin of i^{th} middlemen (A_{mi})

where,

A_{mi} = Market margin of i^{th} middlemen

P_{ri} = Total value of receipts per unit (Sale price)

P_{pi} = Purchase value per unit (Purchase price)

C_{mi} = Cost incurred on marketing per unit by the i^{th} middlemen Total marketing cost

$$C = C_f + C_{m1} = C_{m2} + C_{m3} + \ldots\ldots + C_{mn}$$

where,

C = Total cost of marketing of the commodity

C_F = Cost paid by the producer from the time the produce leaves the farm till he sells it

C_{mn} = Cost incurred by the n_{th} middlemen in the process of buying and selling the produce.

RESULTS AND DISCUSSION

Socio-economic characteristics of sample respondents

The socio-economic characteristics of the respondents reveal understanding of the sample's age, literacy level, landholding, and experience of the farmers as well as other supply chain stakeholders.

A perusal of Table 1 detailed that larger proportion of sample farmers and market middlemen were of middle aged which was 56.67 per cent and 60 per cent respectively. About 38.33 and 40 per cent of sample farmers and market middlemen completed their secondary school education. Most of the farmers in the sample were medium farmers (46.66%) followed by small farmers (26.67%), large farmers (16.67%) and marginal farmers (10.00%). About 43.33 per cent of the sample farmers were cultivating maize in less than one hectare of land. 31.67 per cent, 21.67 per cent and 3.33 per cent were cultivating maize in 1 to 2 hectares, 2 to 10 hectares and

Table 1. Socio-Economic Particulars of Sample Respondents

Particulars	No. of farmers	No. of market intermediaries
Age		
20 – 40 years (Young)	15 (25.00)	3 (30.00)
40 – 60 years (Middle)	34 (56.67)	6 (60.00)
Above 60 years (Old)	11 (18.33)	1 (10.00)
Literacy		
Illiterate	18 (30.00)	1 (10.00)
Primary	10 (16.67)	2 (20.00)
Secondary	23 (38.33)	4 (40.00)
Higher secondary education and above	9 (15.00)	3 (30.00)
Land holding		
Marginal (< 1 ha)	6 (10.00)	-
Small (1-2 ha)	16 (26.67)	-
Medium (2-10 ha)	28 (46.66)	-
Large (>10 ha)	10 (16.67)	-
Acreage under maize by sample farmers		
Less than 1 ha	26 (43.33)	-
1-2 ha	19 (31.67)	-
2-10 ha	13 (21.67)	-
More than 10 ha	2 (3.33)	-
Experience in Farming/Trading		
Less than 5 years	1 (1.67)	0
5 – 10 years	7 (11.67)	4 (40.00)
10 – 15 years	3 (5.00)	2 (20.00)
Greater than 15 years	49 (81.66)	4 (40.00)

more than 10 hectares of land respectively. From the results it was found that, about 81.66 per cent of farmers had more than 15 years of farming experience, 11.67 per cent had 5-10 years of experience, 5 per cent had 10-15 years of experience and 1.67 per cent of farmers had less than 5 years of farming experience. Further 40 per cent of market intermediaries had more than 15 years of trading experience as well as 5-10 years experience followed by and 20 per cent had 10 – 15 years of experience and 40 per cent had 5-10 years of experience.

Existing supply chains of maize in the study area

Four supply chain channels of maize were identified in Rangareddy district of Telangana State. The identified channels were

Channel – I : Producer – Hatcheries

Channel – II : Producer – Commission agent – Hatcheries

Channel – III : Producer – Wholesaler – Hatcheries

Channel – IV : Producer – Commission agent – Wholesalers – Hatcheries

Among the four channels enlisted above, channel I was the shortest channel. As there were no intermediaries in the channel, this channel stood as most efficient among all the channels. When the producer was unable to sell the produce directly to the end customer *i.e.,* hatcheries, then he took the help of commission agents in the village.

This constituted as channel II. This channel would be preferred by the producer when the market is nearer. Channel III also constituted three stakeholders. The produce went to wholesaler and the wholesaler sold it to the end customer i.e., hatcheries. The producer preferred selling to wholesaler as the wholesaler would be helpful to the producer in terms of weighing, transport and also financial help when required. Channel IV was constituted with four stakeholders. The produce first go to the village level commission agent then to wholesalers and finally to hatcheries. Among the four channels listed above, 46.47 per cent of farmers followed channel I, 28.33 per cent followed channel II, 18.33 per cent followed channel III and only 6.67 per cent followed channel IV (Table 2).

Table 2. Number and Percentage of sample farmers following each channel

	No of farmers	Percentage of farmers
Channel I	28	46.67
Channel II	17	28.33
Channel III	11	18.33
Channel IV	4	6.67

Estimation of price spread in various identified maize supply chains

Marketing cost and margin of maize at producer level was varied according to selected market, method of sale, quantity of marketed surplus, distance from production point to market and type of storage materials (Srikanth *et al.,* 2017).

Among the four marketing channels, Channel I has the least marketing cost per quintal of maize followed by Channel II, Channel III and Channel IV. The respective marketing costs per quintal of maize in the above market channels determined out to be 100.20, 128.04, 231.27 and 259.11 rupees respectively. (Table 3)

In marketing channel I, entire marketing costs were borne by the producer alone. An amount of ₹ 58.50 (58.38%) was incurred on transportation of maize from villages to the hatcheries, packaging expenditure was ₹ 19.76 (19.72%) and loading, unloading and weighment charges was ₹ 21.94 (21.90%) per quintal. Hence sum of marketing cost incurred by the producer which is also the total marketing cost of the channel was ₹ 100.20 per quintal. In marketing channel II, commission agent helps the producer to move the product from producer to hatcheries. In this channel in addition to the transportation cost (45.69%), packaging cost (15.43%), loading, unloading and weighment charges (17.14% and commission agent charges occupied 21.74 per cent of the total marketing cost of the channel II. The sum of total marketing cost incurred by producer and also the total marketing cost of the supply chain II was ₹ 128.04 per quintal. In marketing channel III the producer takes his produce to nearby wholesale market and the transportation cost incurred was ₹ 53.75 (23.24%) with packaging ₹ 19.76 (8.53%), loading, unloading and weighment charges includes ₹ 17.74 (7.67%). In marketing channel III the sum of total marketing cost incurred by the producer was ₹ 91.25 (39.46%). The transportation cost incurred by the wholesaler was ₹ 47.99 (20.75%), costs for grading and packing ₹ 19.48 (8.42%), loading and unloading charges ₹ 40.00 (17.30%) and cost on marketing fee includes ₹ 32.55 (14.07%) respectively. The total marketing cost born by the wholesaler was ₹ 140.02 (60.54%), In sum, the total marketing cost incurred in supply chain III was ₹ 231.27. In marketing channel IV the total marketing cost incurred by the producer was ₹ 119.09 (45.96%) which includes transportation cost, ₹ 53.75 (20.74%), packaging ₹ 19.76 (7.63%), loading, unloading and weighment charges ₹ 17.74 (6.85%) and commission charges ₹ 27.84 (10.74%) respectively. The marketing cost born by the wholesaler is ₹ 140.02 (54.04%) and it includes transportation charges from wholesale market to hatcheries ₹ 47.29 (18.52%), costs for grading and packing ₹ 19.48 (7.52%), loading and unloading charges ₹ 40.00 (15.44%) and marketing fee ₹ 32.55 (12.56%). Thus the total marketing cost of the supply chain IV was ₹ 259.11.

In supply chain I and II the entire marketing cost was born by the farmer alone. In supply chain III and IV 39.46 and 45.96 per cent of the marketing cost was paid by the farmer respectively. In all the supply chains transportation costs was the major component in the total marketing cost. Balvant Pagi and Gangadevi (2018) also reported that transportation cost occupied a major portion in marketing of maize, in tribal areas of middle Gujarat.

Marketing costs and marketing margins of the identified supply chains were calculated to assess the share of different agencies involved in the supply chain along with producers share in consumers rupee are shown in Table 4. Producers share in consumer rupee varied from one channel to another channel depending upon the marketing agencies involved. Producers share in consumers rupee was highest (93.83%) in channel I. The same was 91.98 per cent, 84.33 per cent and 82.66 per cent

Table 3. Marketing costs involved in different marketing channels of maize: (per quintal)

S. No.	Particulars	Channel I	Channel II	Channel III	Channel IV
1	**Producer**	-	-	-	-
	Transportation	58.50 (58.38)	58.50 (45.69)	53.75 (23.24)	53.75 (20.74)
	Packaging	19.76 (19.72)	19.76 (15.43)	19.76 (8.53)	19.76 (7.63)
	Loading, Unloading and Weighment charges	21.94 (21.90)	21.94 (17.14)	17.74 (7.67)	17.74 (6.85)
	Commission Agent's margin	-	27.84 (21.74)	-	27.84 (10.74)
	Sub Total Cost	100.20 (100.00)	128.04 (100.00)	91.25 (39.46)	119.09 (45.96)
2	**Wholesaler**	-	-	-	-
	Transportation costs	-	-	47.99 (20.75)	47.99 (18.52)
	Grading	-	-	19.48 (8.42)	19.48 (7.52)
	Loading and unloading	-	-	40.00 (17.30)	40.00 (15.44)
	Marketing Fee	-	-	32.55 (14.07)	32.55 (12.56)
	Sub Total Cost	-	-	140.02 (60.54)	140.02 (54.04)
	Total Costs	**100.20 (100.00)**	**128.04 (100.00)**	**231.27 (100.00)**	**259.11 (100.00)**

in channel II, channel III and channel IV respectively. In marketing channel I the producers directly sells his produce to the hatcheries and hence incur ₹ 100.20 per quintal of produce towards marketing cost. and received a net price of ₹ 1524.43. In marketing channel II the producer takes the help of commission agent to sell his produce to hatcheries, hence the marketing cost incurred was ₹ 128.04 per quintal of produce. Farmer received a net price of ₹ 1468.75. In marketing channel III the producers sells his produce to wholesaler. The marketing costs incurred by the producer was ₹ 91.25 per quintal of maize and the net price received by the farmer was ₹ 1415.87. The wholesaler incurred ₹ 140.02 towards marketing costs and ₹ 31.77 towards marketing margin. The margin realized by the wholesaler was 1.89 per cent of consumers rupee. In marketing channel IV both commission agent and wholesaler involves in marketing of the produce. The marketing costs incurred by the farmer was ₹ 119.09 which was 7.10 per cent of the consumers rupee. The net price realized by the farmer was ₹ 1387.03 per quintal of maize. The marketing cost and margins enjoyed by the wholesaler was ₹ 140.02 and ₹ 31.77 respectively.

From the results it was noticed that there was a huge difference in price spread of channels where there was no intervention of market intermediaries and the channels with market intermediaries. Similar results also reported by Chauhan and Kumar (2010).

Estimation of Marketing efficiency in various identified maize supply chains

Marketing efficiency of identified supply chains of maize were estimated using Conventional, Shepherd, and Acharya's Approach. Marketing efficiency in identified supply chains is presented in Table 5. Conventional method suggest that channel III (1.14) was more efficient than channel IV (1.12), channel II (1.00), and channel I (1.00). But in this channel producers share in consumers rupee was less in this channel. Hence this channel was

Table 4. Price spread in Supply chain of Maize (per quintal)

S. No.	Particulars	Channel I	Channel II	Channel III	Channel IV
1.	**Producer**				
	Price received by farmer	1624.63 (100.00)	1596.79 (100.00)	1507.12 (89.77)	1506.12 (89.76)
	Marketing costs	100.20 (6.17)	128.04 (8.02)	91.25 (5.44)	119.09 (7.10)
	Net price/Producers share in consumers rupee	1524.43 (93.83)	1468.75 (91.98)	1415.87 (84.33)	1387.03 (82.66)
2.	**Wholesaler**				
	Purchase price	-	-	1507.12 (89.77)	1506.12 (82.66)
	Marketing costs	-	-	140.02 (8.34)	140.02 (8.34)
	Margin	-	-	31.77 (1.89)	31.77 (1.89)
3.	Hatcheries purchase price	1624.63 (100.00)	1596.79 (100.00)	1678.91 (100.00)	1677.91 (100.00)

Table 5. Marketing efficiency across various supply chain channels of Maize

S. No	Particulars	Unit	Channel I	Channel II	Channel III	Channel IV
1	Hatcheries purchase price	₹ $quintal^{-1}$	1624.63	1596.79	1678.91	1677.91
2	Total marketing costs (MC)	₹ $quintal^{-1}$	100.20	128.04	231.27	259.11
3	Total net margins of intermediaries	₹ $quintal^{-1}$	-	-	31.77	31.77
4	Net price received by the farmers (FP)	₹ $quintal^{-1}$	1524.43	1468.75	1415.87	1387.03
5	Value added (1-4)	₹ $quintal^{-1}$	100.20	128.04	263.04	290.88
6	Index of marketing efficiency					
a	Conventional Method (5 ÷ 2)		1.00	1.00	1.14	1.12
b	Shepherd Approach (1 ÷ 2)		16.21	12.47	7.26	6.48
c	Acharya Approach (4 ÷ (2+3))		15.21	11.47	5.38	4.77

not suggestive if maximization of farmers share is the objective.

Shepherd's method suggest that channel I (16.21) was more efficient than channel II (12.47), channel III (7.26), and channel IV (6.48). Acharya's method also suggest that channel I (15.21) was more efficient than channel II (11.47), channel III (5.38), and channel IV (4.77).

From the results above, it was concluded that channel I was more efficient than the other marketing channels as the farmers are directly selling their produce to hatcheries. Most of the farmers who are having good quality of produce and not depending on market intermediaries for capital requirement were selling their produce directly to hatcheries. Those farmers who were depending on marketing intermediaries for their capital requirement for raising the maize crop were approaching marketing channels II, III, and IV. Kumar and Chahal (2011) also observed the highest marketing efficiency in the channel where no market intermediaries involved.

Transportation places a very important role in marketing of maize, a well developed transportation system reduces the transportation cost and increases the efficiency of the marketing system. Credit facilities should be made available to the farmers so that their dependency on market intermediaries can be reduced. Establishing Farmers Producers Organizations can eliminate the involvement of market intermediaries, and increases the price received by the farmers.

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ECONOMIC ANALYSIS OF PRODUCTION OF SWEET ORANGE IN ANANTAPURAMU DISTRICT OF ANDHRA PRADESH

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ABSTRACT

The present study aims at examining the economic viability of sweet orange in Anantapuramu district of Andhra Pradesh. Forty sweet orange farmers constituted the sample for the study. Data collected from primary sources have been analyzed with the set objectives using appropriate techniques. Average establishment cost was worked out to be ₹ 326479 per hectare of sweet orange. The gross returns per hectare of sweet orange has been worked out to be ₹ 1479465 during 5 to 10 years age, ₹ 4001250 (11 to 20 years age) and ₹ 3072630 (21 to 30 years age). The farmers were receiving a net income of ₹ 22487.66 through inter crops during pre bearing period. Even after taking the returns from intercrops, the farmer has to bear a loss of ₹ 303991.34 during pre bearing period. The net returns obtained were ₹ 1024650 during 5 to 10 years age to ₹ 3237878 (11 to 20 years) and ₹ 2294163 (21 to 30 years age). The net present value, benefit-cost ratio and internal rate of return were ₹ 2,192, 536.87, 3.04 and 23.6 per cent. The findings of the study show that sweet orange was a profitable and promising enterprise for the driest district of Andhra Pradesh state. There was a greater scope for setting up of processing industry for sweet orange which helps to the growers to realize better price for their produce, which also generates employment. Given the fruit product diversity, that also spreads in terms of production across seasons, the farmers may be encouraged to form producer's societies on a co-operative basis to market their produce and also realize higher value for their produce.

KEYWORDS: Sweet orange, Establishment costs, Discounted measures and Economic Analysis.

INTRODUCTION

Horticulture sector shows an enormous potential to raise the farmers income, provide livelihood security and earn foreign exchange through exports. India is the second largest Producer of fruits and Vegetables in the world, contributing about 9.3 per cent share of total world production. In 2020-21, the production of horticultural crops recorded an enormous production of 326.6 million tones (MT) which is more than the total food grain production (Abhishek *et al.,* 2021). Further there was a change in the consumer preferences across all expenditure classes towards fruits and vegetables (Sarma *et al.,* 2018). This increasing trend in production of horticultural crops was also observed in sweet orange in India, where the area under sweet orange increased from 157 to 191 thousand hectares from 2010-11 to 2019-20. India had made fairly good progress in sweet orange production for the same period with increased production from 1316 thousand tones to 3483 thousand tones. The yield of sweet orange has raised from 8.4 to 18.23 tonnes per ha during the above period. In India sweet orange is majorly grown in the states of Andhra Pradesh, Karnataka, Telangana, Maharashtra and Gujarat. In the year 2018, the sweet orange production in the state of Andhra Pradesh was 2003.11 thousand tonnes (Anonymous, 2020). Anantapuramu district ranked first both in area (31,693.45 ha) and production (34.83 lakh tonnes) of sweet orange in Andhra Pradesh. Sweet orange contains large amounts of potassium, which might help to prevent high blood pressure and stroke. The fruit and juice also contain large amounts of a chemical called citrate, which might help to prevent kidney stones. Citrate tends to bind with calcium before it can form a stone. In this background the present study was focused on economic analysis of production of sweet orange in Anantapuram district of Andhra Pradesh.

MATERIAL AND METHODS

Multistage purposive random sampling method was adopted to select the ultimate sample for the study. Anantapuramu district was purposively selected for the present study as it has the highest area under sweet orange in Andhra Pradesh. Based on acreage under sweet orange. top two mandals *i.e.,* Tadipatri and Mudigubba were selected for the study. Using the same criteria top two villages from each mandal were selected. From each village 10 sweet orange farmers were selected randomly, thus the total sample for the study was 40. Primary data was collected for the agricultural year 2020-21 through personal interview with the help of a well structured schedule. To know the costs and returns simple arithmetical tools were employed and the financial feasibility of sweet orange orchards was analysed using discounted measures like NPW (Net Present Worth), B-C ratio (Benefit Cost ratio) and IRR (Internal rate

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of Return). Bhat *et al.* (2011) also employed these discounted measures to study the economic appraisal of kinnow production under north-western Himalayan region of Jammu.

RESULTS AND DISCUSSION

Socio-economic profile of selected orchardists

This provides a comprehensive understanding of the composition of type of farmers, education status, average size of farm holding and asset structure of the selected farm respondents. The results presented in Table 1 revealed that 45.00 per cent of the sample respondents were large farmers, 30.00 per cent of them were medium farmers and 25.00 per cent were small farmers. Majority of the farmers (45.00%) had their primary education, 22.50 per cent were illiterates, 17.50 per cent had secondary education and 15.00 per cent studied up to college level. The land holding particulars of the respondents presented in Table 2 disclosed that the average size of the land holding of the sample respondents was 5.23 ha and of the total holding, 81.84 per cent constituted the dry land and the remaining was irrigated land (18.16%). Further 81.26 per cent of the total holding of the respondents was under sweet orange cultivation. The income earned by the farmers and the risk bearing ability of the farmers largely depends on the value of the assets owned by them. From the results it was found that land value constituted a major item of the total assets (90.10%). The value of other assets like farm buildings, live stock, bore well, motor and other irrigation equipment and machinery and implements constitutes only 9.90 per cent (Table 3) of the total value of the assets.

Resources and resource services utilization on sweet orange orchards

Production of sweet orange requires material inputs *viz.,* planting material, Farm Yard Manure, plant protection chemicals *etc.,* as well as resource services like human labour, machinery etc. The value of these resources and resource services forms cost structure of sweet orange production. On an average the sample farmers were maintaining a plant population of 220 grafts per hectare. The quantity of manures varied from 16 tonnes per hectare during the establishment period to 18.6 tonnes per hectare during 5 to 10 years, 37 tonnes per hectare in the 11 to 20 years and 28 tonnes per hectare in the 21 to 30 years age of the orchard. The use of N, P, K nutrients in the form of DAP, single super phosphate and murate of potash for sweet orange orchard stood at 193, 158 and 277 kg per hectare per annum during 0 to 4 years age, 290, 180 and 290 kg per hectare from 5 to 10 years, 712, 348 and 402 kg per hectare from 11 to 20 years and 804, 514 and 522 kg per hectare during 21 to 30 years age of orchards respectively. There was an increase in the application of N, P, K from 11th year onwards on commencing of economic yields. Plant protection chemicals were applied in the form of dusts (sulphur, carbendazem + mancozeb) and liquids (dichlorvous, imadachloprid). The quantity of dusts and liquids applied to control pests and disease were 20 kg and 14 lit per hectare per annum during 0 to 4 years age,

Table 2. Average size of land holding of the sweet orange orchardists

S. No.	Particulars	Area in hectares	Percentage
1.	Dryland	4.28	81.84
2.	Irrigated land	0.95	18.16
3.	**Total holding**	**5.23**	**100.00**
4.	Area under sweet orange	4.25	81.26

Table 1. Type of Farmers and educational status in the Selected Orchardists

Socioeconomic character	Particulars		No. of Respondents	Percentage
1. Type of farmers	Large farmers (>10 ha)		18	45.00
	Medium farmers (2-10 ha)		12	30.00
	Small farmers(<2 ha)		10	25.00
		Total	**40**	**100.00**
2. Education status	Illiterates (not educated)		9	22.50
	Primary(1 to 5th class)		18	45.00
	Secondary(6th to 10th class)		7	17.50
	College (intermediate and degree)		6	15.00
		Total	**40**	**100.00**

Table 3. Asset Structure of the orchardists of sweet orange farms

S. No.	Particulars	Sweet orange farms	
		Value	Percentage
1	Value of land	1611836	90.10
2	Value of farm buildings	19365	1.10
3	Value of livestock	17042	1.00
4	Value of bore well, motor and other irrigation equipment	81826	4.60
5	Value of machinery and implements	59320	3.30
6	Value of assets		
	a. With land	1789389	100.00
	b. Without land	177553	9.90

Table 4. Material input utilization on sweet orange orchard per hectare of an average farmer

S. No.	Particulars	Age of the orchard (Years)			
		0 to 4	5 to 10	11 to 20	21 to 30
1	Plant material(number)	220	–	–	–
2	Manures (tonnes)	16	18.6	37	28
3	Fertilizers (kgs)				
	DAP	193	290	712	804
	MOP	158	180	348	514
	SSP	277	290	402	522
4	Plant protection chemicals				
	Dust (kgs)	20	25	42	58
	Liquid (litres)	14	32	45	52

25 kg and 32 lit from 5 to 10 years age, 42 kg and 45 lit from 11 to 20 years age and 58 kg and 52 lit per hectare from 21 to 30 years age. It was clearly inferred that the quantity of plant protection chemicals increased with increase in the age of the orchard.

The total labour requirement for the cultivation of sweet orange during its economic life period was 971 man days ha^{-1} (Table 5). It was noted that major labour consuming operations were application of FYM, inter cultivation, application of plant protection chemicals, irrigation and application of fertilizers. Pruning and removal of flowers operations were undertaken only during the establishment period only, Hence, these operations required less labour about 16 mandays ha^{-1} in sweet orange orchards. The operations which are performed only once in the life period of orchard were pitting, planting, staking, fencing and gap filling took still lesser share of labour. Majority of the farmers in the study area go for dispose of the standing crop to the pre harvest contractor. The farmers believe that it is a safety measure against the fluctuations in prices of sweet orange. Hence there was no human labour utilization for harvesting operation in the study area. It is evident from Table 6 that the machine power utilized by sweet orange farmers was 199.5 hrs per hectare during the entire economic life of sweet orange. The machine power was used for operations like land preparation, inter-cultivation and sprayings.

Costs and returns from sweet orange orchards

Sweet orange was a perennial commercial crop can be cultivated economically for about 30 years. It takes four years to establish and starts yielding from fifth year onwards. Therefore, the costs incurred in establishing the orchard during the pre-bearing period at current prices of inputs and input services were considered as

Table 5. Human labour utilization per hectare of sweet orange orchard

S. No.	Particulars	0 to 4 Years		5 to 10 Years		11 to 20 Years		21 to 30 Years		Total	
		Mandays	Percentage	Mandays	Percentage	Mandays	Percentage	Mandays	Percentage	Mandays	Percentage
1	Pitting	14	8.22	-	-	-	-	-	-	14	1.44
2	Planting	8	4.37	-	-	-	-	-	-	8	0.82
3	Staking	1	0.75	-	-	-	-	-	-	1	0.10
4	Application of FYM	36	20.69	43	25.29	79	25.73	75	23.44	233	24.00
5	Application of fertilizers	13	7.64	23	13.53	39	12.70	50	15.63	125	12.87
6	Intercultivation (weeding)	19	10.69	37	21.76	78	25.41	85	26.56	219	22.55
7	Pruning etc.	9	5.00	-	-	-	-	-	-	9	0.93
8	Removal of flowers	7	3.79	-	-	-	-	-	-	7	0.72
9	Plant protection	33	18.97	39	22.94	60	19.54	65	20.31	197	20.29
10	Irrigation	18	10.46	28	16.47	51	16.61	45	14.06	142	14.62
11	Fencing	15	8.79	-	-	-	-	-	-	15	1.54
12	Gap filling	1	0.69	-	-	-	-	-	-	1	0.10
	Total	**174**	**100.06**	**170**	**100.00**	**307**	**100.00**	**320**	**100.00**	**971**	**100.00**

Table 6. Machine labour utilization per hectare of sweet orange orchard

Particulars	Age of the orchard (Years)				
	0 to 4	5 to 10	11 to 20	21 to 30	Total
Machine labour (Hours)	20.5	31	36	32	119.5

establishment costs. The establishment costs include the expenditure on land preparation, pitting, laying of irrigation channels, fencing, plant material, planting, pruning, removal of flowers and other subsequent operations in nurturing the orchard together with fixed costs. Results presented in Table 7, indicated that the total establishment cost of sweet orange was ₹ 326479 per hectare. The highest cost item of expenditure was rental value of owned land which was estimated to ₹ 98840 per hectare, that constitute 30.27 per cent followed by wages to human labour ₹ 86960 per hectare contributing 26.64 per cent, planting material ₹ 26400 (8.09%), Farm Yard Manure ₹ 24784 (7.59%), Machine labour ₹ 24599 (7.53%). Pokharkar *et al.* (2016) reported similar observation in their study on economics of production of Guava in western Maharashtra. Annual maintenance costs included the costs incurred to maintain the orchard from 5th year onwards up to the economic life period of the orchard. It is clear from the results that the annual maintenance cost per hectare increased with the increase in the age of the orchard. This is because of higher expenses incurred on various inputs and input services. This increase may be attributed to the direct relationship between the input requirement and age of the plant. The annual maintenance cost ranges from ₹ 207036 during 5 to 10 years age to ₹ 350408 during 11 to 20 years and ₹ 365503 during 21 to 30 years age. Similar results were also reported by Sharma *et al.* (2006).

Data presented in Table 8 indicates the costs and returns per hectare of sweet orange orchard at different ages. From the results it was observed that there was no production of sweet orange up to the age of four years, economic yields were obtained only from five years of age. The per hectare production of sweet orange starts increasing gradually from nearly 85.31 tonnes per hectare during 5 to 10 years age to 242.5 tonnes per hectare for 11 to 20 years age and 186.22 hectares for 21 to 30 years age. The gross returns from sweet orange were worked out to be ₹ 1479465 during 5 to 10 years age, ₹ 4001250 (11 to 20 years age) and ₹ 3072630 (21 to 30 years age). After deducting the operational costs along with fixed costs like depreciation, rental value of owned land, interest on fixed capital, annual share of establishment costs from gross returns, the net returns were worked out for sweet orange. Intercropping is possible in sweet orange during pre bearing period as there will be enough space left in between rows and plants and this enables the orchardists to earn income as orchard plants do not produce any returns during this period. Normally in the study area intercropping is taken up by groundnut, green gram and black gram. The per hectare net returns for a period of four years from inter crops in sweet orange was ₹ 22487.66. Raj *et al.* (2019) also observed returns from inter crops in guava plantation during pre bearing period. Even after taking the returns from intercrops, the farmer has to bear a loss of ₹ 303991.34 during pre bearing period. During the fifth year onwards the net returns becomes positive. The net returns were worked out to be ₹ 1024650 during 5 to 10 yeas age to ₹ 3237878 (11 to 20 years) and ₹ 2294163 during 21 to 30 years age.

Economic feasibility of sweet orange orchard

In the present study, the costs and returns had been discounted at 6 per cent to estimate the present worth of future returns. The net present value, benefit-cost ratio and internal rate of return for sweet orange orchards were worked out and presented in Table 9. The overall NPV of sweet orange orchard on per hectare at 6 per cent discount rate is found to be ₹ 2,192,536.87. The formal selection criterion of NPV is to accept all the projects with positive values. Applying this principle, net present value of sweet orange orchard clearly indicates its financial reliability in the study area. The decision in the B-C ratio framework is to select the projects where the ratio is more than one. In the overall farms B-C ratio has been estimated as 3.04 at 6 per cent discount rate which satisfies the rule indicating the worthiness of investment on sweet orange orchard. Similar findings were also observed by Parameshwar *et al.* (2018) in their study on sweet orange. The benefit-cost ratio indicates expected returns for each rupee of investment in sweet orange orchard. Thus, it can be concluded that investment in sweet orange orchard is economically viable and financially feasible in the area under study. The formal selection criterion of IRR is to accept the projects with IRR more than the opportunity cost of capital. The internal rate of return of the overall farms has been estimated as 23.6 per cent. The IRR represents the maximum rate of interest at which the growers can borrow from lending agencies and invest on sweet orange orchard. Since IRR is more than the opportunity cost of capital it clearly indicates that investment on sweet orange orchard is a financially sound and economically viable proposition in the study area.

In the light of above discussion, it may be concluded that even though the establishment cost of sweet orange is very high yet it is an economically viable enterprise.

Table 7. Cost structure of sweet orange orchard

S. No.	Particulars	0 to 4 Years		5 to 10 Years		11 to 20 Years		21 to 30 Years	
		Amount (₹)	Share (%)	Amount (₹)	Share (%)	Amount (₹)	Share (%)	Amount (₹)	Share (%)
	Operational Costs								
1	Human Labour wages	86960	26.64	85110	18.71	153450	20.10	167325	21.49
2	Machine(tractor) hire charges	24599	7.53	37200	8.18	43200	5.66	38400	4.93
3	Planting material	26400	8.09		0.00		0.00		0.00
4	FYM	24784	7.59	28811	6.33	57313	7.51	43372	5.57
5	Fertilizers	12224	3.74	15429	3.39	32179	4.22	40992	5.27
6	Plant protection chemicals	14685	4.50	25150	5.53	38310	5.02	48340	6.21
7	Interest on working capital @8%	15172	4.65	15336	3.37	25956	3.40	27074	3.48
8	Total operational costs	204824	62.74	207036	45.52	350408	45.90	365503	46.95
	Fixed costs								
9	Depreciation	15929	4.88	23894	5.25	39823	5.22	39823	5.12
10	Rental value of owned land	98840	30.27	148260	32.60	247100	32.37	247100	31.74
11	Interest on fixed capital @ 6%	6886	2.11	10329	2.27	17215	2.26	17215	2.21
12	Annual share of establishment costs			65296	14.36	108826	14.26	108826	13.98
13	Total fixed costs	121655	37.26	247779	54.48	412964	54.10	412964	53.05
14	**Total costs**	326479	100.00	454815	100.00	763372	100.00	778467	100.00

Table 8. Returns of sweet orange (₹ ha^{-1})

S. No.	Particulars	0 to 4 Years	5 to 10 Years	11 to 20 Years	21 to 30 Years
1.	Yield (tonnes) ha^{-1}	-	85.31	242.5	186.22
2.	Gross returns ha^{-1}	-	1479465	4001250	3072630
3.	Total costs ha^{-1}	326479	454815	763372	778467
4.	Net returns from Intercrops	22487.66	-	-	-
	Net returns ha^{-1}	-303991.34	1024650	3237878	2294163

Table 9. Estimates of economic viability of sweet orange orchards

S. No.	Particulars	Discount rate (6%)
1	NPW	₹ 2,192,536.87
2	Benefit-cost ratio	3.04
3	IRR (%)	23.6

Per hectare establishment cost was worked out to be ₹ 326479. The annual maintenance cost ranges from ₹ 207036 during 5 to 10 years age to ₹ 350408 (11 to 20 years) and ₹ 365503 (21 to 30 years age). The net returns were worked out to be ₹ 1024650 during 5 to 10 yeas age to ₹ 3237878 (11 to 20 years) and ₹ 2294163 (21 to 30 years age). The economic viability of the sweet orange, the net present worth, benefit cost ratio and internal rate of return have been worked out as ₹ 2192536.87, 3.04 and 23.6 per cent respectively. This indicated that sweet orange was a economically viable enterprise. The results had proven that sweet orange had a vital potential in raising the incomes of the farmer.

POLICY IMPLICATION AND SUGGESTION

1. It was found out from the study that the orchardists were unaware of the importance of maintaining optimum plant population, application of nutrients in required doses and hence the agricultural department has to play an important role in educating the farmers in adopting the package of practices.

2. Sweet orange cultivation provides a greater scope for setting up of processing industry which in turn helps the growers to realize better price for their produce, which also generates employment.

3. Given the fruit product diversity, that also spreads in terms of production across seasons, the farmers may be encouraged to form producer's societies on a co-operative basis to market their produce and also realize higher value for their produce.

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EFFECT OF WEATHER PARAMETERS ON PROSO MILLET (*Panicum miliaceum* L.) CULTIVARS UNDER DIFFERENT SOWING WINDOWS

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ABSTRACT

A field experiment was conducted during *Kharif* season 2021 at Dryland Farm, S.V. Agricultural College, Tirupati, Andhra Pradesh, ANGRAU. To know the effect of weather parameters on proso millet crop under three dates of sowing i.e. first fortnight of June (D_1), second fortnight of June (D_2) and first fortnight of July (D_3) and three varieties *i.e.* CO 5 (V_1), TNAU 202 (V_2) and GPUP 8 (V_3) with three replications. Proso millet sown on I FN (* first fortnight) of June and variety GPUP 8 utilized more Growing Degree Days, Photothermal Units and Heat Use Efficiency compared to II FN of June and I FN of July. Among the three sowing windows crops sown in II FN of June (D_2) and cultivar, CO 5 (V_1) produced significantly higher straw yield, total dry matter, grain yield and monetary returns.

KEYWORDS: Growing Degree Days, Heat Use Efficiency, Monetary returns, Photothermal Units.

INTRODUCTION

Proso millet (*Panicum miliaceum)* also called as common millet, hog millet belongs to the Gramineae family, is a short duration crop and a significant minor millet, with high nutritional value and protein level of 11–12 per cent (Kalinova and Moudry, 2006). It adapts well to different soils and climatic conditions. The crop can thrive both on the plateau and at higher elevations. The chromosome number is 2n = 36. It is a self-pollinated crop; cross-pollination can occur up to 10 per cent. It is a short-day plant that will grow up to a height of 90 to 120 cm. The root system is adventitious. Profuse branching and tillering are found in Indian grown proso millet. Stems and leaves have slight hairs. The panicle is inflorescence.

As it is a C_4 crop, it utilizes water effectively and is drought-resistant. Because of its rapid maturity, the crop can withstand drought. Due to its short life span, it escapes from drought. The optimum base temperature is 10°C. Development of proso millet is linked with temperature using Growing Degree Days (GDD) (Tonapi *et al*., 2015).

The amount of land under millet cultivation is rapidly diminishing. The COVID-19 pandemic has shown the fragility and frailty of our current food system. A millet-based agricultural system is unavoidable due to its high nutritious value and ability to grow in a wide range of climatic conditions. Optimum sowing time and selection of improved cultivars play a remarkable role in exploiting the yield potential of crops under particular agro-climatic conditions. It governs the crop phenological development and the efficient conversion of biomass into economic yield.

Growing suitable varieties at an appropriate time is essential for ensuring optimum crop productivity. Temperature is an important environmental factor influencing the growth and development of crop plants. It influences crop phenology and yield (Bishnoi *et al*., 1995). Sowing of proso millet at an optimum time ensures a better harmony among soil, plant and atmospheric system. The variation in sowing time brings out varied plant environment interaction, which determines the efficiency of inherent physiological processes and ultimately the crop yield.

MATERIAL AND METHODS

This field experiment was carried out during *Kharif,* 2021 in Dryland Farm, S.V. Agricultural College, Tirupati campus of Acharya N.G. Ranga Agricultural University which falls under the Southern Agro-climatic Zone of Andhra Pradesh and is geographically situated at 13.5 °N latitude, 79.5 °E longitude, with an altitude of 182.9 m above the mean sea level. Three dates of sowing *i.e.,* first fortnight of June (I FN) (D_1), second fortnight of June (II FN) (D_2) and first fortnight of July (I FN) (D_3) and three varieties *i.e.,* CO 5 (V_1), TNAU 202 (V_2)

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and GPUP 8 (V_3). The experiment was conducted in spilt plot design with three replications. The soil of the experimental plot was sandy loam in texture, neutral in pH, medium in organic carbon content, low in available nitrogen. The weekly mean maximum temperature during the crop growth period ranged from 30.82°C to 37.13°C, with an average of 33.98°C. The weekly mean minimum temperature during the crop period ranged from 22.07 °C to 26.53°C, with an average of 23.91°C. The weekly mean relative humidity during the crop growth period ranged from 52.5 to 80.0 per cent with an average of 69.77 per cent. During the crop growth period 997.36 mm of rainfall was received in 34 rainy days. Mean bright sunshine hours during the crop growth period ranged from 0.7 to 10.50 h day^{-1} with an average of 4.5 h day^{-1}. Seed rate at the rate of 10 kg ha^{-1} was taken by mixing with sand and were placed at 2 cm depth in an open furrow and covered thoroughly. The spacing adopted was 22.5 cm × 10 cm.

Data on weather parameters *viz.,* Temperature (Maximum and Minimum) (°C), Relative Humidity (%), Rainfall (mm), Evaporation (mm) and Bright sunshine hours (hours day^{-1}) are collected. Based on the above observations, the following Agrometeorological indices like Growing Degree Days (GDD), Photo Thermal Units (PTU) and Heat Use Efficiency (HUE) were computed during different phases of proso millet by adopting the procedure given by Rajput (1980). GDD was expressed in terms of °C day.

$$\text{GDD (°C)} = \sum\left(\frac{T_{max} + T_{min}}{2}\right) - T_b$$

where,

T_{max} = maximum temperature (°C)

T_{min} = minimum temperature (°C) and

T_b = Base temperature = 10°C (Narcico *et al.,* 1992).

The accumulated PTU was determined by the following formula (Monteith, 1984).

The unit of PTU is °C day hr.

$$\text{PTU} = \text{GDD} \times \text{Day length (hrs)}$$

where, day length refers to the maximum possible sunshine hours.

Heat Use Efficiency (HUE) for economic yield *i.e.,* grain yield, (kg ha^{-1}) was calculated using the following formula. The unit of it is kg ha^{-1}°C day^{-1}.

$$\text{HUE} = \frac{\text{Grain yield}}{\text{GDD}}$$

RESULTS AND DISCUSSION

The grain yield as influenced by dates of sowing varied significantly according to the statistical analysis. The variety sown during the II FN of June (D_2) gave significantly higher grain yield of 2059.3 kg ha^{-1}, followed by the I FN of June of 1581.7 kg ha^{-1}. However, the lowest grain yield was recorded in I FN of July (D_3) (1254.3 kg ha^{-1}) which is 39 per cent less compared with II FN of June (D_2) sowing.

The higher yield values in II FN of June (D_2) could be attributed to optimum environmental conditions for the growth and development of the crop which might enhance the accumulation of photosynthates from source to sink.

Sowing of proso millet on optimum date *i.e.,* II FN of June had resulted in better development of source in the form of dry matter accumulation which contributed to the higher grain yield and good seed set is favored by warm weather prevailed during its maturity. Similar results were reported by Maurya *et al.* (2016).

The higher straw yield of 2909.6 kg ha^{-1} was registered with CO 5 which was significantly superior to the other varieties. The next best was TNAU 202 (2661.1 kg ha^{-1}) and the lower straw yield of 2496.8 kg ha^{-1} was recorded by GPUP 8 and higher straw yield of 3044.5 kg ha^{-1} was obtained when sown during II FN of June and the least was observed in the crop sown on the I FN of July of 2442.2 kg ha^{-1}.

The delayed sowing may hasten the crop phenological development, thereby causing a significant reduction in crop yields. The I FN of July sown crops attained 50 percent flowering earlier than the others. The combined effect of all the growth and yield parameters resulted in increased above- ground biomass yield and grain yield in the II FN of June. Because early sowing increases the length of the growing period that plant might take advantage as favorable growing conditions and accumulates biomass as the highest yields generally result where the growing season is longest.

There was significant difference in total dry matter production with different dates of sowing. The crop

Table 1. Influence of staggered sowing on grain and straw yield, monetary returns and agro climatic indices of proso millet varieties

Treatments	Straw yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Gross returns	Net returns	GDD (°C)	PTU (°C^{-1} day^{-1} hr^{-1})	HUE (kg ha^{-1} °C^{-1} day^{-1}
Dates of Sowing (D)							
D_1 : I fortnight of June	2580.9	1581.7	56685	33165	1542	19281	7937
D_2 : II fortnight of June	3044.5	2059.3	73620	50100	1520	18740	7612
D_3 : I fortnight of July	2442.2	1254.3	45122	21602	1465	17907	7326
SEm ±	54.86	43.69	1208.17	714.98	14.98	261.76	104.40
CD(P = 0.05)	215.40	171.54	4743.88	2807.35	58.80	1027.81	409.92
Varieties (V)							
D_1 : I FN of June	2909.6	1989.0	71069	47549	1426	17635	7255
D_2 : II FN of June	2661.1	1575.3	56500	32980	1459	18097	7426
D_3 : I FN of July	2496.8	1331.7	47858	24338	1641	20197	8194
SEm ±	74.63	54.02	1172.79	799.97	20.21	280.06	117.01
CD(P = 0.05)	229.95	166.45	3613.72	2464.94	62.28	862.95	360.55

sown on the II FN of June recorded the highest dry matter accumulation of 452.3 g m^{-2} and the lowest value (376.1 g m^{-2}) was recorded in the I FN of July at harvest. Moreover, congenial climatic conditions during the first and second dates of sowing are reflected in higher dry matter accumulation. These findings were substantiated by those reported by Deshmukh *et al*. (2013).

The total dry matter production of $plant^{-1}$ differed significantly by the different varieties at all the stages of crop growth as mentioned in the Table 2. The variety V_1 (CO 5) recorded significantly the highest dry matter (429.4 g m^{-2}) followed by V_2 (TNAU 202) and V_3 (GPUP 8) with 414.1 g m^{-2} and 397.3 g m^{-2} respectively. The superiority in dry matter accumulation of CO 5 variety over other two varieties might be due to a high source-sink relationship. The results were corroborative with the findings of Triveni *et al*. (2018) and Raundal and Vidya (2017). This might be due to the early sown crop may receive favorable climatic conditions in terms of temperature and other climatic parameters during various crop growth stages.

Gross returns were higher with the crop sown on the II FN of June (D_2) (73620 ₹ ha^{-1}) which was significantly higher than the crop sown on the I FN of June (D_1) (56685 ₹ ha^{-1}). The lowest was obtained in the last sown one (D_3) (45122 ₹ ha^{-1}) which is 39 per cent less than the highest one. The results were similar to the findings of Detroja *et al*. (2018).

Regarding the varieties tested, higher gross returns were realized with CO 5(V_1) (71069 ₹ ha^{-1}) which was significantly superior to the remaining other varieties. The next best variety was TNAU 202 (V_2) (56500 ₹ ha^{-1}) and the latter variety GPUP 8 (V_3) (47858 ₹ ha^{-1}) registered the lower returns. It might be due to the potential of different varieties.

The highest net returns were obtained with proso millet sown during II FN of June (D_2) (50100 ₹ ha^{-1}) followed by I FN of June (D_1) (33165 ₹ ha^{-1}), while the lower net returns was obtained under July I FN (D_3) (21602 ₹ ha^{-1}) sowing.

Table 2. Influence of staggered sowing on dry matter (g) of proso millet varieties

Treatments	Dry matter (g m^{-2})			
	20 DAS	40 DAS	60 DAS	At Harvest
Dates of sowing (D)				
D_1 : I fortnight of June	7.8	151.4	322.3	412.5
D_2 : II fortnight of June	8.1	176.6	368.4	452.3
D_3 : I fortnight of July	6.9	140.6	301.2	376.1
SEm ±	0.17	2.09	6.63	8.61
CD (P=0.05)	0.66	8.20	26.02	33.80
Varieties (V)				
D_1 : I FN of June	8.3	161.5	337.7	429.4
D_2 : II FN of June	7.3	156.9	331.2	414.1
D_3 : I FN of July	7.0	150.3	323.1	397.3
SEm ±	0.16	2.84	3.69	6.29
CD (P=0.05)	0.48	8.74	11.37	19.4

The optimum time of sowing and favorable weather conditions might have led to a proportionate increase in growth parameters like dry matter production, leaf area index, etc. These results corroborate the findings of Nigade *et al*. (2020)

The data presented in the Table 1 revealed that the GDD reported during I FN of June (D_1) was 1542 °C which was however comparable with II FN of June (D_2) of 1520 °C. The crop sown during I FN of July (D_3) recorded the lower number of growing degree days of 1465 °C throughout its life cycle. D_1 sown crop required more number of days to attain various growth stages. This is due to the existence of favorable conditions for crop growth and development. This is because the GDD which is the function of temperature in turn is a function of bright sunshine hours. The results are in close agreement with the findings of Londhe *et al.* (2020).

Among the different varieties of proso millet, the variety GPUP 8 registered the maximum number of growing degree days 1641°C. The mean heat unit requirement for the variety TNAU 202 was 1459°C. The minimum number of growing degree days was taken by the variety CO 5 (1426°C). The GPUP 8 exhibited the highest growing degree days as it is exposed to the sun for more period than the other two varieties.

The data presented in the Table 1 revealed that a significantly higher number of photothermal units reported during I FN of June (D_1) was 19281°C day hr which was followed by II FN of June (D_2) of 18740°C day hr. The crop sown during I FN of July (D_3) recorded the lower number of photothermal units of 17907°C day hr. This might be due to the presence of cloudiness, lower temperature and lower sunshine hours for more days under the timely sown condition in comparison to late sown crops. Similar results are reported by Chakravarty and Sastry (1983).

Among the different varieties of proso millet, the variety GPUP 8 registered the maximum number of photothermal units of 20197°C day hr. The photothermal units required for the variety TNAU 202 was 18097°C day hr. The minimum numbers were taken by the variety CO 5 (17635°C).

The data presented in the Table 1 revealed that a significantly highest heat use efficiency was reported during I FN of June (D_1) was 7937 kg ha^{-1} °C^{-1} day^{-1} which was followed by II FN of June (D_2) of 7612 kg ha^{-1} °C^{-1} day^{-1}. The crop sown during I FN of July (D_3) recorded a lower heat use efficiency of 7326 kg ha^{-1} °C^{-1} day^{-1}. HUE value decreased correspondingly with each delay in sowing. This is in conformity with results reported by Girijesh *et al*. (2011).

Generally higher HUE is attributed to the higher yield but slight variations are noted. As the temperature was optimum throughout the growing period, it utilized heat more efficiently and increased biological activity. In contrast, low temperature and higher duration hampered normal biological activities resulting in lower yield as well as lower HUE. A similar relationship was also expressed by Thavaprakaash *et al*. (2007).

Based on the investigation of suitable varieties and dates of sowing, it can be concluded that the June II FN sowed was found to be the optimum time of sowing for proso millet in the southern agro-climatic zone of Andhra Pradesh, with the highest grain yield across all the genotypes.

All the varieties shows decreased grain yield on the late dates of sowing. A greater reduction in yield at the third date of sowing in GPUP 8 (59.00%) compared with the CO 5 on the second date of sowing. Among the genotypes tested CO 5 (V_1) was found to be best followed by TNAU 202 (V_2).

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INFLUENCE OF ORGANIC WEED MANAGEMENT PRACTICES ON GROWTH AND YIELD OF MAIZE (*Zea mays* L.)

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ABSTRACT

Field experiment entitled "Organic weed management in maize (*Zea mays* L.)" was conducted during *rabi*, 2021-22 at Wetland Farm of S.V. Agricultural College, Tirupati, Andhra Pradesh, India. Among all the organic weed management practices, significantly higher dry matter production, yield attributes and kernel yield were recorded with corn gluten meal @ 3.5 t ha^{-1} as PE *fb* HW at 30 DAS (W_9) over rest of the treatments. The next best treatment was hand weeding twice at 15 and 30 DAS (W_1), however it was at par with groundnut shells mulch @ 12.5 t ha^{-1} (W_2) and mango leaves mulch @ 5 t ha^{-1} (W_4). Mango leaves mulch @ 5 t ha^{-1} resulted in higher net returns, which was at par with hand weeding twice at 15 and 30 DAS (W_1) and groundnut shells mulch @ 12.5 t ha^{-1} (W_2). Finally, the present study has concluded that mango leaves mulch @ 5 t ha^{-1} or groundnut shells mulch @ 12.5 t ha^{-1} is considered to be the most effective, sustainable and economical weed management practice in maize under organic farming.

KEYWORDS: Corn gluten meal, Maize, Mulch, Organic and Weed management.

INTRODUCTION

Maize (*Zea mays* L.) is considered as queen of the cereals and is one of the most important crop next to rice and wheat in global agriculture. Maize is grown in 194 million ha area over more than 170 countries across the globe with 1148 million MT of production (2020-21). Among the maize growing countries, India ranks 4th in area and 7th in production representing around 4 per cent of world maize area and 2 per cent of total production. During 2020-21 in India, it is grown in 9.89 million ha area with 31.65 million tonnes of production and with a productivity of 3199 kg ha^{-1} (Anonymous, 2021).

Maize being a widely spaced crop, gets infested with number of weeds and subjected to heavy weed competition which often causes huge losses in yield ranging from 28 to 100 per cent (Patel *et al*., 2006). Maize is sensitive to weeds especially during early stages of development and thus weed infestation from germination to 45 DAS causes maximum reduction in yield.

Modern agriculture is productivity oriented and depends mainly on synthetic inputs namely herbicides to manage the weeds. Continuous non-judicious use of herbicides for weed management will cause loss of biodiversity, environmental pollution and develops herbicide resistance in weeds. However in the current scenario of agriculture, evolving an eco-friendly, sustainable and economical approach of weed management is more advisable so as to protect our environmental resources such as soil flora and fauna including human being and animals in a holistic manner. Organic crop growers face weed control as their greatest difficulty in crop production because they are not allowed to use chemical herbicides. Hence, a strong need was felt to find the non-chemical methods of weed management practices in organic maize production system.

MATERIAL AND METHODS

A field experiment was conducted during *rabi* season of 2021-22 at Wetland Farm, S.V. Agricultural College, Tirupati, located at 13.5°N latitude and 79.5°E longitude with an altitude of 182.9 m above mean sea level in the Southern Agroclimatic Zone of Andhra Pradesh, India. The soil was sandy clay loam in texture, neutral in soil reaction, low in organic carbon and available nitrogen, and medium in available phosphorus and potassium. The experiment was laidout in randomized block design with ten weed management practices and three replications. The treatments consisted of hand weeding twice at 15 and 30 DAS (W_1), groundnut shells mulch @ 12.5 t ha^{-1} (W_2), saw dust mulch @ 5 t ha^{-1} (W_3), mango leaves

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mulch @ 5 t ha^{-1} (W_4), live mulching with 2 rows of cowpea (W_5), live mulching with 2 rows of sunhemp (W_6), eucalyptus leaf extract spray @ 15 l ha^{-1} at 15 and 30 DAS (W_7), sunflower extract spray @ 18 l ha^{-1} at 15 and 30 DAS (W_8), corn gluten meal 3.5 t ha^{-1} as PE *fb* HW at 30 DAS (W_9) and weedy check (W_{10}).

Maize hybrid '*DHM-117'* was raised with recommended package of practices except for the weed management practices. The crop was sown on 26th October, 2022 and recommended dose of fertilizers was 240-80-80 kg N, P_2O_5 and K_2O ha^{-1}. Full dose of phosphorous and potassium were applied as basal and nitrogen was applied in three equal splits *viz*., 1/3rd as basal, 1/3rd at knee high stage and the remaining 1/3rd at tasseling stage. Weed management practices were imposed as per the treatments. The different organic mulches were applied on the day of sowing in between the rows of maize. Live mulches were grown up to 40 DAS, uprooted and spread on the soil surface. The required quantities of filtered concentrated plant water extracts were sprayed at 15 and 30 DAS. Data on different parameters were recorded and statistically analyzed following the analysis of variance for RBD as given by Panse and Sukhatme (1985). Weed index was calculated by employing formula given by Tripathi *et al.,* (1971).

$$WI = \frac{X - Y}{X} \times 100$$

WI = Weed index (%)

X = Yield obtained from minimum weed competition plot

Y = Yield obtained from treated plot

RESULTS AND DISCUSSION

Weed flora

The weed flora associated with maize belongs to thirteen taxonomic families, of which the predominant weed species were *Dactyloctenium aegyptium* (L.) Willd (36.00%), *Cyperus rotundus* L. (22.00%), *Digitaria sanguinalis* (L.) Scop. (18.00%), *Boerhavia erecta* L. (11.00%), *Commelina benghalensis* L. (6.00%), *Euphorbia hirta* L. (3.00%) and others (4.00%).

Effect of organic weed management practices on maize

The results revealed that different organic weed management practices significantly improved the dry matter accumulation, cob length, kernel weight cob^{-1}, hundred kernel weight, kernel yield and net returns over weedy check (Table 1).

Dry matter production

Dry matter production of maize at harvest was significantly influenced by various organic weed management practices (Table 1). Dry matter production was significantly higher with corn gluten meal @ 3.5 t ha^{-1} as PE *fb* HW at 30 DAS (W_9) over rest of the treatments at harvest of maize. The higher dry matter accumulation in W_9 is might be due to pre emergence herbicidal activity of corn gluten meal, that have controlled weeds in the initial stages of the crop growth and later emerged weeds were effectively removed by hand weeding imposed at 30 DAS and it also contains 10 per cent nitrogen content by weight, which might have accelerated the plant growth and is reflected as higher dry matter. The next best treatment was hand weeding twice at 15 and 30 DAS (W_1), however which was at par with groundnut shells mulch @ 12.5 t ha^{-1} (W_2) and mango leaves mulch @ 5 t ha^{-1} (W_4). The higher dry matter was owing to significant reduction in density and dry matter of weeds that helps for greater penetration of solar radiation in the crop canopy, higher rate of photosynthesis and more accumulation of dry matter. Similar findings were also reported by Stanzen *et al*. (2017). Significantly lower dry matter production was registered with weedy check (W_{10}) due to heavy weed infestation lead to shorter plant height with less foliage and dry matter production.

Yield attributes and Yield

Cob length, kernel weight cob^{-1}, hundred kernel weight and kernel yield of maize differed significantly due to organic weed management practices (Table 1).

Higher yield attributes *viz*., cob length, kernel weight cob^{-1} and hundred kernel weight and kernel yield of maize were registered with corn gluten meal @ 3.5 t ha^{-1} as PE *fb* HW at 30 DAS (W_9), which was significantly superior over rest of the treatments. Hand weeding twice at 15 and 30 DAS (W_1) was the next best, however it was at par with groundnut shells mulch @ 12.5 t ha^{-1} (W_2) and mango leaves mulch @ 5 t ha^{-1} (W_4). This might be

Table 1. Growth, yield attributes, kernel yield, weed index and net returns of maize as influenced by organic weed management practices

Treatments	Dry matter production (kg ha^{-1})	Cob length (cm)	Kernel weight cob^{-1} (g)	Hundred kernel weight (g)	Kernel yield (kg ha^{-1})	Weed index (%)	Net returns (? ha^{-1})
W_1 : Hand weeding twice at 15 and 30 DAS	13325	17.3	96.5	30.3	6412	20.29 (12.03)	72616
W_2 : Groundnut shells mulch @ 12.5 t ha^{-1}	13112	17.2	91.2	29.7	6272	21.92 (13.95)	70952
W_3 : Saw dust mulch @ 5 t ha^{-1}	8671	13.1	58.5	23.1	3558	45.67 (51.19)	23344
W_4 : Mango leaves mulch @ 5 t ha^{-1}	13009	16.9	88.3	29.4	6225	22.45 (14.59)	73850
W_5 : Live mulching with 2 rows of cowpea	11319	15.4	76.1	27.5	4916	34.78 (32.55)	50688
W_6 : Live mulching with 2 rows of sunhemp	11017	15.1	74.7	26.6	4847	35.36 (33.50)	50346
W_7 : Eucalyptus leaf extract spray @ 15 l ha^{-1} at 15 and 30 DAS	9312	13.5	63.5	24.6	4036	41.90 (44.62)	38254
W_8 : Sunflower extract spray @ 18 l ha^{-1} at 15 and 30 DAS	9037	13.4	61.8	23.8	3952	42.62 (45.78)	36736
W_9 : Corn gluten meal @ 3.5 t ha^{-1} as PE *fb* HW at 30 DAS	14413	18.6	108.2	32.2	7289	0.00 (0.00)	1408
W_{10} : Weedy check (control)	6872	11.6	45.3	20.3	2653	52.88 (63.60)	18206
SEm ±	248.4	0.44	3.29	0.56	195.4	1.09	1559.8
CD (P = 0.05)	738	1.2	9.3	1.7	586	3.2	4634

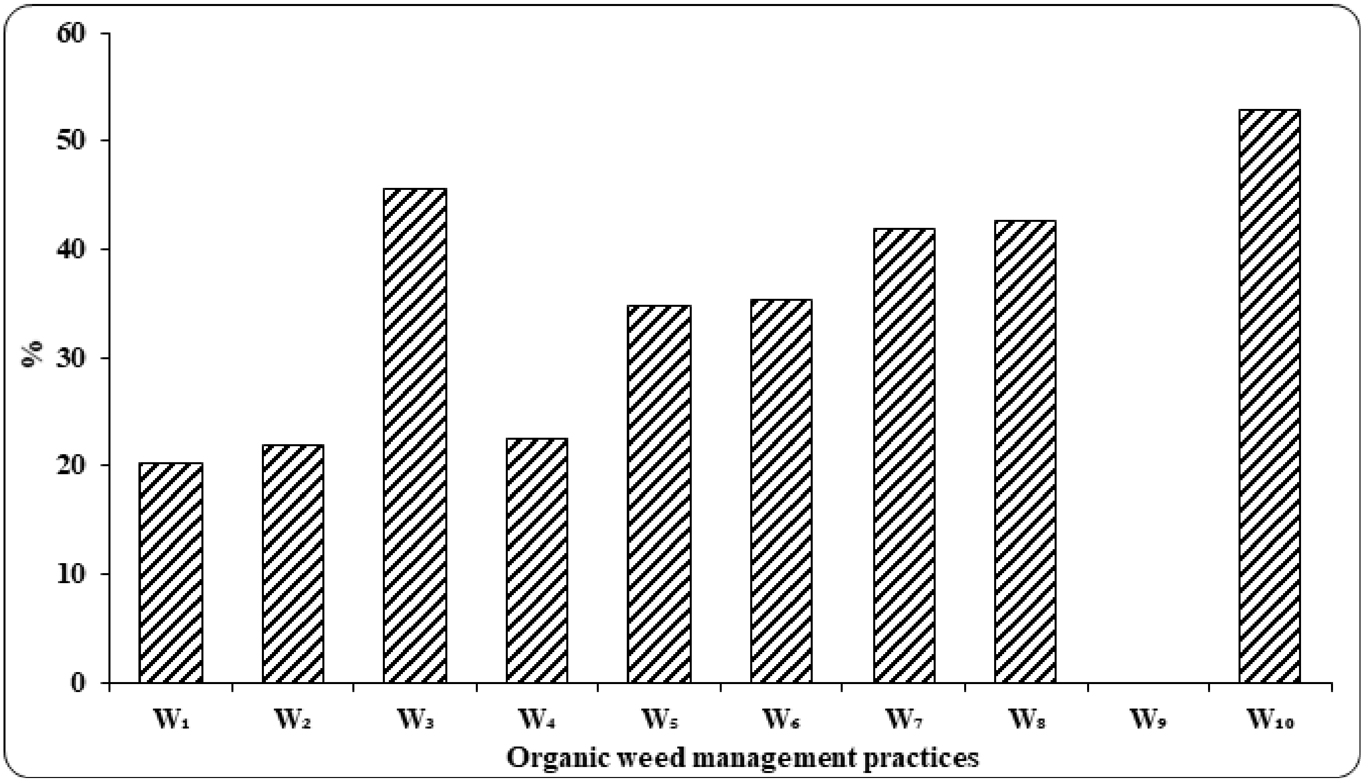

Figure 1. Weed index (%) of maize as influenced by organic weed management practices

due to lower crop weed competition for growth resources throughout the crop growing period enabling the crop for maximum utilization of nutrients, moisture, light and space, which enhanced the vegetative and reproductive potential of the crop that might have reflected in the form of higher yield attributes and kernel yield of maize. Similar results were also reported by Mahto *et al*. (2020), Stanzen *et al*. (2017) and Barad *et al*. (2016). Yield attributes and kernel yield were significantly lower with weedy check (W_{10}) when compared to rest of the weed management practices.

Weed index

Weed index refers to yield reduction due to presence of weeds in comparison to the best weed management practice. So, lower the weed index higher the weed control by that weed management practice. Corn gluten meal @ 3.5 t ha^{-1} as PE *fb* HW at 30 DAS (T_9) was considered as the best treatment for calculating weed index as it recorded higher kernel yield. The lowest weed index was noticed with hand weeding twice at 15 and 30 DAS (W_1), which was in parity with groundnut shells mulch @ 12.5 t ha^{-1} (W_2) and mango leaves mulch @ 5 t ha^{-1} (W_4). This might be due to maintenance of weed free environment during the entire growth period of the crop resulting in increased kernel yield of maize. These findings are in close conformity with those reported by Mathukia *et al*. (2014). Higher weed index was registered with weedy check (W_{10}) (Table 1 and Fig. 1.).

Net returns

Significantly higher net returns were realized with mango leaves mulch @ 5 t ha^{-1} (W_4), however it was comparable with hand weeding twice at 15 and 30 DAS (W_1) and groundnut shells mulch @ 12.5 t ha^{-1} (W_2). This might be due to increased yields and reduced cost of cultivation in the above treatments. Corn gluten meal @ 3.5 t ha^{-1} as PE *fb* HW at 30 DAS (W_9) recorded significantly lower net returns, when compared to rest of the treatments due to high cost of corn gluten meal (Table 1).

Corn gluten meal @ 3.5 t ha^{-1} as PE *fb* HW at 30 DAS (W_9) realized higher kernel yield, but not economical due to high cost of cultivation. Finally, the present study has indicated that wherever the labour availability for hand weeding is abundant and cheaper, one can go for hand weeding or opt for mango leaves mulch @ 5 t ha^{-1} or groundnut shells mulch @ 12.5 t ha^{-1} taking into economical considerations for obtaining broad-spectrum weed control and enhanced productivity of maize under organic farming systems.

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ECOFRIENDLY BIOPESTICIDES FOR THE MANAGEMENT OF RED FLOUR BEETLE, *Tribolium castaneum* (Herbst) IN STORED RICE

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ABSTRACT

In the present study essential oils like neem-azal, clove oil and acorus oil were tested at different concentrations for the management of red flour beetle, *Tribolium castaneum* (Herbst). Neem-azal at 2.0 per cent was found to be effective with LC_{50} value of 1.11 per cent and LT_{50} value of 2.4 days followed by acorus oil 15.0 per cent with LC_{50} value of 16.43 and LT_{50} value of 4.30 days against *Tribolium* larvae. Neem-azal at 2 per cent was found effective with LC_{50} of 0.99 per cent and LT_{50} value of 15.78 hours followed by clove oil 15.0 per cent with LC_{50} of 11.30 per cent and LT_{50} value of 45.07 hours against *Tribolium* adults.

KEYWORDS: Neem-azal, Clove oil, Acorus oil, LC_{50}, LT_{50}.

INTRODUCTION

The post harvest losses of food grains occur at different levels of storage from harvesting up to consumption. Abiotic and biotic factors are of major concern for losses of stored grains in the world. Among the biotic factors insect pests, rodents, mites and fungi contribute major portion of damage. Out of these post-harvest losses due to insects alone accounts for 2.0 to 4.2 per cent followed by rodents 2.50 per cent (IGMRI, 2020). Stored grains and their products are attacked by many insect pests as internal and external feeders.

The red flour beetle, *Tribolium castaneum* is an external feeder and feeds on broken rice, flour, cereals, meal, beans, spices and other stored products. Control of these insects relies heavily on the use of chemical insecticides and fumigants, which has led to problems such as negative impact on environment, residual toxicity, development of resistance to insecticides and lethal effects on non-target organisms (Abhijit *et al*., 2018). Indiscriminate and continuous use of synthetic insecticides and fumigants like phosphine in poorly sealed warehouses at sub lethal doses resulted in the development of resistance in many of the stored grain pests especially in bulk storage facilities and rice storage godowns. In view of resistance of stored grain pests, suitable alternative strategies like use of safer plant products like essential oils can be explored for the management of *T. castaneum* in stored rice.

The essential oils of spices, herbs, aromatic plants and their extracts possess insecticidal properties *viz.,* antifeedant, repellent and fumigant action. They are eco-friendly, relatively specific in mode of action, easy to use, less hazardous, less expensive, safer to non target organisms and readily available (Compolo *et al*., 2018)

Neem, *Azadirachta indica* contains many properties like insecticidal, ovicidal, antifeedant and growth inhibiting effects against many insect pests due to presence of triterpenoid, azadirachtin and other biochemical compounds such as nimbin, nimbidin and salanin (Choupanian *et al*., 2017). The essential oils isolated from the clove buds, *Syzygium aromaticum* is widely used and well known for its medicinal properties. It exhibits different insecticidal properties like inhibition of oviposition, insecticidal activity, prevention of adult emergence with isoeugenol being particularly active compound (Abo-El-Saad *et al*., 2011). Sweet flag, *Acorus calamus* is a herbaceous perennial and the rhizomes of the plants were found to have insecticidal, ovicidal, antifeedant and repellent activities with bioactive compounds like α-asarone and β-asarone (Abhijit *et al*., 2018).

In the present study, effect of essential oils like neem-azal, clove oil and acorus oil were studied against red flour beetle, *T. castaneum* in stored rice.

MATERIAL AND METHODS

Maintenance of insect culture

Tribolium mother culture was collected from rice storage godown of RARS, Tirupati, Chittoor district (13.6288°N, 79.4192°E), Andhra Pradesh and reared in plastic containers (11 cm × 8 cm) containing broken rice

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added with 5 per cent yeast in the insectary, Department of Entomology, S.V. Agricultural College, Tirupati under ambient storage conditions. The newly emerged F1 adults and larvae were separated and used for bioefficacy studies.

Preparation of different concentrations

The essential oils *viz.,* Neem-azal, Clove oil and Acorus oil used in this study were procured from Indian Scientifics, Tirupati. Different test concentrations of essential oils were prepared using acetone as a solvent by serial dilution method. Neem-azal of 1.5 and 2.0%, Clove oil of 10.0 and 15%, Acorus oil of 10 and 15% were prepared. Three replications of each treatment were maintained along with an untreated control.

Bioassay studies using diet incorporation method

The efficacy of essential oils was evaluated against larvae of *T. castaneum* using diet incorporation method (Ganesh *et al.,* 2020). The Rice grains were mixed with formulations at different test concentrations. Two hundred (200) µl of formulation was added to 20 grams of broken rice and the plastic containers of measurement (11 cm × 8 cm) were shaken manually for 5 minutes for uniform distribution. Each treatment was replicated thrice and 20 larvae (6-7 days old) were released into each plastic container. The containers were closed with muslin cloth for sufficient ventilation and kept in ambient laboratory conditions of 30°C temperature and 70 per cent relative humidity. The mortality counts were taken at 1, 3, 5, 7 and 10 days after exposure. Insects were considered dead which were without any leg or antenna movements after prodding with a fine brush.

Bioassay test using filter paper impregnation method

The Filter Paper Impregnation Method (FPIM) was used for testing contact toxicity of formulations (Manal *et al.,* 2018). The filter papers (Whatman) were trimmed into appropriate sizes and laid in a labelled Petri dish. Three replications of each treatment were maintained along with an untreated control.

Essential oils of different concentrations were evaluated using filter paper impregnation method against the adults of *T. castaneum*. All oils were diluted to different concentrations using water as solvent for neem-azal and acetone as solvent for other formulations. One ml of each concentration was applied to filter paper which was placed in Petri dishes and allowed for evaporation of solvent. After evaporation of solvent, 20 adults were released into each Petri dish. Each treatment was replicated three times along with untreated control. Adult mortality was recorded at 24, 48 and 72 hours after treatment.

Statistical Analysis

Based on the per cent mortality count, LC_{50}, LC_{90} and LT_{50} values were calculated through probit analysis using the SPSS statistical package for determining their effectiveness against larvae and adults of *T. castaneum.* The larval mortality and adult mortality were subjected to angular transformation. The data was statistically analyzed using SPSS software.

RESULTS AND DISCUSSION

Among the different essential oils against *T. castaneum* larvae, neem-azal at 1.5% and 2.0% was found to be highly effective with 100 per cent mortality at 10 DAT followed by acorus oil 15% and clove oil 15% with 86.66 and 76.66 per cent respectively (Table 1). Whereas larvae pupated after 10 days in untreated control.

Probit analysis revealed LC_{50} at 1.11, 19.54 and 16.43 per cent for neem-azal, clove oil and acorus oil respectively and LC_{90} at 6.42, 244.49 and 110.74 per cent for neem-azal, clove oil and acorus oil respectively (Table 3). LT_{50} of 2.40, 4.31 and 4.30 days were obtained for neem-azal @ 1%, clove oil @ 10% and acorus oil @ 10% respectively (Table 4).

Bioassay test against *Tribolium* adults revealed complete 100 per cent mortality at both concentrations of neem-azal followed by acorus oil @ 15% (90%) and clove oil @ 15% (83.33%) compared to zero per cent mortality in untreated control at 72 HAT (Table 2).

Probit analysis revealed LC_{50} at 0.99, 11.30 and 11.68 per cent for neem-azal. clove oil and acorus oil respectively and LC_{90} at 2.08, 25.25 and 26.32 per cent for neem-azal, clove oil and acorus oil respectively (Table 5). LT_{50} of 15.78, 45.07 and 45.76 hours were obtained for neem-azal, clove oil and acorus oil respectively (Table 6).

Results of present study are in agreement with findings of Abhijith *et al.,* (2018) who studied efficacy of acorus oil using filter paper impreganation method and recorded 100 per cent mortality in *Lasioderma serricorne* and *Cryptolestes ferrugineus* adults when treated with acorus oil 10 per cent after 60 hours after treatment. Rashmi *et al.* (2019) recorded repellent activity of neem oil against *T. castaneum* which showed 88.31, 95.08 and

Table 1. Effect of essential oils on larval mortality of red flour beetle, *T. castaneum*

Treatment	Per cent larval mortality*				
	1 DAT	3 DAT	5 DAT	7 DAT	10 DAT
Neem-azal 1.5%	26.66 (31.00)^{b}	53.33 (46.92)^{b}	83.33 (66.14)^{a}	96.66 (83.86)^{a}	100.00 (90.00)^{a}
Neem-azal 2.0%	36.66 (37.22)^{a}	70.00 (57.00)^{a}	93.33 (77.71)^{a}	100.00 (90.00)^{a}	100.00 (90.00)^{a}
Clove oil 10.0%	16.66 (23.86)^{c}	36.66 (37.22)^{d}	43.33 (41.15)^{d}	53.33 (46.92)^{d}	70.00 (56.79)^{c}
Clove oil 15.0%	23.33 (28.78)^{b}	36.66 (37.22)^{d}	53.33 (46.92)^{c}	73.33 (59.00)^{c}	76.66 (61.22)^{c}
Acorus oil 10.0%	23.33 (28.78)^{b}	33.33 (35.22)^{d}	50.00 (45.00)^{c}	56.66 (48.85)^{d}	63.33 (52.78)^{d}
Acorus oil 15.0%	26.66 (31.00)^{b}	40.00 (39.23)^{c}	63.33 (52.78)^{b}	73.33 (59.00)^{c}	86.66 (68.86)^{b}
Untreated control	0.00 (0.91)^{d}	0.00 (0.91)^{e}	0.00 (0.91)^{e}	0.00 (0.91)^{e}	0.00 (0.91)^{e}
SEd	11.04	13.79	18.66	20.67	23.80
F value	2.79	4.01	4.07	4.88	3.84

DAT-Days after treatment; *Mean of three replications; Figures in parentheses are angular transformed values; Means followed by same letters are not significantly different by DMRT

Table 2. Efficacy of essential oils on adult mortality of red flour beetle, *T. castaneum* in stored rice

Treatment	Per cent adult mortality*		
	24 HAT	48 HAT	72 HAT
Neem-azal 1.5%	73.33 (59.00)^{b}	90.00 (71.57)^{b}	100.00 (90.00)^{a}
Neem-azal 2.0%	90.00 (71.57)^{a}	100.00 (90.00)^{a}	100.00 (90.00)^{a}
Clove oil 10.0%	36.67 (37.22)^{c}	50.00 (45.00)^{c}	60.00 (50.85)^{c}
Clove oil 15.0%	76.67 (61.22)^{b}	80.00 (63.43)^{c}	83.33 (66.14)^{b}
Acorus oil 10.0%	33.33 (35.22)^{c}	53.33 (46.92)^{c}	60.00 (50.85)$_{c}$
Acorus oil 15.0%	73.33 (59.00)^{b}	80.00 (63.43)^{c}	90.00 (75.00)^{ab}
Untreated control	0.00 (1.07)^{d}	0.00 (1.07)^{d}	0.00 (1.07)^{d}
SEd	21.18	22.69	27.36
F value	2.86	3.62	2.92

HAT-Hours after treatment; *Mean of three replications; Figures in parentheses are angular transformed values; Means followed by same letters are not significantly different by DMRT

Table 3. LC_{50} and LC_{90} of three essential oils against *T. castaneum* larvae at 2 DAT

Treatment	LC_{50} value (%)	Fiducial limits (95 %)		LC_{90} value (%)	Fiducial limits		Slope ± SE	Intercept ± SE	Chi square value
		Upper	Lower		Upper	Lower			
Neem-azal	1.11	1.33	0.95	6.42	15.17	4.06	1.68 ± 0.26	-0.07 ± 0.05	2.78
Clove oil	19.54	31.29	14.79	244.49	133.10	104.45	1.16 ± 0.20	-1.50 ± 0.20	4.39
Acorus oil	16.43	45.16	10.97	110.74	468.08	41.95	1.55 ± 0.20	-1.88 ± 0.21	5.80

LC: Lethal concentration

Table 4. LT_{50} of three essential oils against *T. castaneum* larvae

Treatment	LT_{50} value (Days)	Fiducial limits (95 %)		Slope ± SE	Intercept ± SE	Chi square value
		Upper	Lower			
Neem-azal @ 1.0%	2.40	3.52	1.25	2.31± 0.18	-0.88± 0.12	19.08
Clove oil @ 10.0%	4.31	5.96	2.79	2.06± 0.14	-1.31± 0.12	30.28
Acorus oil @ 10.0 %	4.30	6.73	2.32	1.78± 0.13	-1.14± 0.11	42.96

LT: Lethal time

Table 5. LC_{50} and LC_{90} of three essential oils against *T. castaneum* adults in contact toxicity test

Treatment	LC_{50} value (%)	Fiducial limits (95 %)		LC_{90} value (%)	Fiducial limits		Slope ± SE	Intercept ± SE	Chi square value
		Upper	Lower		Upper	Lower			
Neem-azal	0.99	1.07	0.93	2.08	2.44	1.85	4.00± 0.32	0.04± 0.64	1.30
Clove oil	11.30	15.17	8.54	25.25	57.01	17.95	3.67± 0.29	-3.86± 0.31	10.29
Acorus oil	11.68	15.60	8.95	26.32	58.79	18.70	3.63± 0.29	-3.88± 0.32	9.50

LC: Lethal concentration

Table 6. LT_{50} of three essential oils against *T. castaneum* adults in contact toxicity test

Treatment	LT_{50} value (HAT)	Fiducial limits (95 %)		Slope ± SE	Intercept ±SE	Chi square value
		Upper	Lower			
Neem-azal @ 1.5 %	15.78	11.34	24.67	3.15 ± 0.58	-3.77 ± 0.89	4.21
Clove oil @ 10.0 %	45.07	66.22	33.83	1.23 ± 0.37	-2.05 ± 0.62	0.48
Acorus oil @ 10.0 %	45.76	60.41	35.63	1.46 ± 0.38	-2.42 ± 0.62	0.28

LT: Lethal time

97.81 per cent repellent activity at 1, 2 and 3 per cent neem oil respectively. Mantzoukas *et al.* (2020) reported insecticidal activity of neem oil @ 3 per cent against *Tribolium confusum*, *Oryzaephilus surinamensis* and *Plodia interpunctella* larvae and pupae with 100 per cent mortality.

Shukla *et al.* (2009) reported that acorus rhizome powder (5 mg/g seed) was found more efficacious with 100 per cent ovicidal activity and completely inhibited F_1 adult emergence at a lower dose than that of leaf powders on chick pea seeds against *Callosobruchus chinensis.* Ali *et al.* (1983) reported that neem oil @ 1.00 per cent had brought 100.00 per cent grub mortality accounting to zero per cent adult emergence in green gram.

Rajasri *et al*., (2014) studied efficacy of neem formulations on pulse beetle and reported that all the neem formulations *viz.*, NSK powder, neem cake, neem leaf powder, neem oil and neem-azal against *C. chinensis* in stored black gram up to 15 months of storage and among all neem formulations neem-azal found effective as compared to other formulations.

The essential oils *viz*., neem-azal @ 2%, acorus oil @ 15% and clove oil @ 15% were found to be highly effective against red flour beetle larvae and adults in stored rice and hence these safer biopesticides can be used for ecofriendly management of *T. castaneum* in stored rice.

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ASSESSMENT OF FEED AND FODDER AVAILABILITY AND REQUIREMENT IN ANDHRA PRADESH

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ABSTRACT

The present study aimed to estimate the feed and fodder demand for the existing livestock population and supply in Andhra Pradesh. For the study the secondary data was collected from the different sources. The livestock population was converted into Ruminant Livestock Units (RLU) based on the species, age and sex. Ruminant Livestock Units (RLU) were considered to have a body weight of 350 kg and a dry matter intake of 2 per cent of their body weight. The total RLU in the state is 9.24 million, requiring 23.61 million tonnes of feed and fodder on dry matter basis. Availability of dry fodder and concentrates were estimated using appropriate conversion ratios to different crop production while green fodder was estimated by applying per hectare yield to different fodder sources The total annual availability of feed and fodder in the state was estimated to be 33.13 million tonnes against the requirement of 23.61 million tonnes and thereby excess of around 40.35 per cent per annum. The availability of feed and fodder was excess in 9 districts except for the Visakhapatnam, Prakasam, Kadapa and Anantapuram districts of the state. Average dry matter availability in the state was 9.82 kg/RLU/day against the requirement (7 kg). Creation of fodder banks and transport fodder to the deficit areas of the country are the policies to be developed and need priority attention to solve the problem of fodder in deficit areas.

KEYWORDS: Dry matter availability, Dry matter requirement and Ruminant Livestock Unit.

INTRODUCTION

India is primarily an agricultural country, with about three-quarters of the population relying on agriculture, livestock, and related industries for a living. Rural areas are home to over 70 per cent of the country's population. Furthermore, rural areas are home to almost 80 per cent of the country's poor (40.7 million). They even provide rural poor households who seem to be landless and small landowners both financial help and food. Agriculture and cattle have long been intertwined in India, providing income for the rural population even during years of drought or inadequate rainfall.

Livestock is a major component of the Indian economy. A total of 30.5 million individuals makes their living from cattle. Livestock rearing is a fundamental section of Indian agriculture supporting the livelihood of nearly two-thirds of the Indian rural population (Karthik *et al.,* 2021). In addition to genetics, the availability of feed resources is crucial for maximizing cattle and poultry output (Ayele *et al.,* 2021). The growth rate of livestock decreased from 3.82 per cent to 2.58 per cent which is a worrisome sign considering that the share of livestock in the agriculture sector is 60.56 per cent and it contributes 11.69 per cent to GDP (Source: Agriculture in Budget 2020-2021, India). According to the Economic Survey 2020-2021, India, agriculture's contribution to the gross domestic product (GDP) has risen to about 20 percent for the first time in the past 17 years, making it the only area of the GDP's performance that is expected to improve in 2020–21. Cattle that were fed crop wastes or straw from grains such as rice, wheat, maize, jowar, and bajra, as well as straw or a bhusa supplemented with green fodder, and are currently grazing on pasture and gauche (grazing) fields. Cattle are fed with different varieties of feeds, including dry fodder, green fodder, and concentrates (Oil cakes, Grains, Bran, and Chuni). The availability of fodder from cultivable land, forests, pastures, and grazing lands has an impact on livestock development and growth in the future.

Fodder is a substantial component of animal feed, accounting for two-thirds of the total demand. It is critical to boost fodder output by expanding under cultivation to 12 per cent of total cultivable land and using high yielding fodder crop varieties. Because of the ever-increasing human population pressure, arable land is mostly used for food and cash crops, therefore there is limited likelihood of having excellent quality arable land accessible for fodder production, and until milk production is economically viable for farmers in comparison to other crops.

Feeding well-balanced diet aids in the ultimate production goal for attaining high and sustained output.

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The unavoidable factors such as shift to commercial crops, shrinking of common property resources and shift towards the cultivation of commercial crops were the reasons for depleting the feed and fodder resources. Enhancing the individual productivity in a huge population of low-producing animals is one of the biggest challenges of Indian livestock sector (Thornton, 2010). Quantification of existing feed resources is necessary for the development of efficient feeding strategies and for the judicious utilization of available feed resources (Ranjhan, 1994).

MATERIAL AND METHODS

The study is entirely based on secondary data and it was conducted in Andhra Pradesh to assess the feed and fodder demand to sustain the existing livestock population and supply in the region and the state has a total of 13 districts (Figure 1).

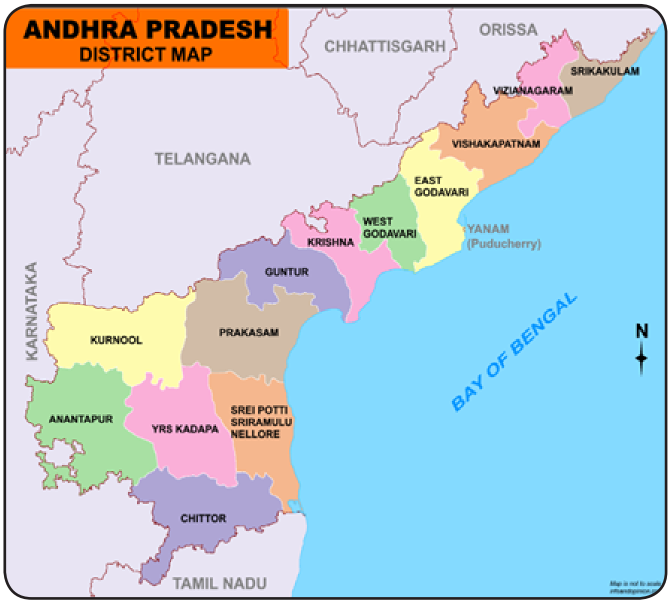

Figure 1. Locale of the study

District-wise data regarding land use, production under different crops, and livestock population were collected from various published sources like Statistical Abstracts of Andhra Pradesh and Seasonal crop reports.

Livestock population in the state was converted into standard ruminant livestock units according to the species, age, and sex-wise (Table 1) and livestock census 2019 data was collected from (GOI, Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture and State Department Animal husbandry, Andhra Pradesh).

Table 1. Conversion factors for calculation of Ruminant Livestock Units (RLU)

Species	Category	Conversion factor
Buffalo	Above 3 years	1.00
	1-3 years	0.50
	Below 1 year	0.17
Cattle	Above 3 years	0.80
	1-3 years	0.34
	Below 1 year	0.11
Sheep	-	0.10
Goats	-	0.10

Source: Raju *et al*. (2002)

District wise requirement for ruminants were calculated based on the ruminant livestock units of 350 kg body weight by assuming 2 per cent dry matter intake per day for every ruminant cattle unit (7 kg dry matter for 350 kg body weight (Ramachandra *et al*., (2007). The dry fodder availability from different crops was assessed from production data for the year 2020-21. The green fodder availability was also estimated using production potential per unit hectare from land classification data.

The land utilization pattern data were classified as Gross Cropped Area (GCA), forest area, cultivable wasteland, permanent pastures, other fallows, area under miscellaneous trees and crops from which green fodder is available for livestock feeding. The availability of green fodder from the gross cropped area (GCA) on the assumption that 4 per cent of the GCA is under folder cultivation with an average yield of 40 tonnes per hectare per year. It was assumed that only 50 per cent of the forest area is available for further production and the average fodder yield is around 3 tonnes per hectare per year. The estimation of green fodder availability is made by using conversion factors is presented in Table 3.

The dry matter content in the crop residues available from different sources has been assumed to be 90 per cent. The dry matter content in the green forage available from different sources has been assumed to be 25 per cent. The dry matter content in the concentrates available from different sources has been assumed to be 90 per cent.

Table 2. Conversion factors for various crops

	Crop Residues	Oil Cakes	Grains	Bran & Chunnies
Paddy	1.30	-	0.02	0.08
Wheat	1.00	-	0.02	0.08
Jowar	2.50	-	0.05	-
Bajra	2.50	-	0.05	-
Barley	1.30	-	0.10	-
Maize	2.50	-	0.10	-
Ragi	2.00	-	0.05	-
Small Millets	2.50	-	0.10	-
Other Cereals	2.00	-	0.10	-
Pulses	1.70	-	-	0.03
Ground nut	2.00	0.7	-	-
Sesamum	-	0.7	-	-
Rape & Mustard	-	0.7	-	-
Linseed	-	0.7	-	-
Niger	-	0.7	-	-
Sunflower	-	0.7	-	-
Safflower	-	0.7	-	-
Soyabean	-	0.7	-	-
Sugarcane	0.25	-	-	-
Coconut	-	0.0625	-	-
Cotton	-	0.0499	-	-

Source: Raju *et al*. (2002)

RESULTS AND DISCUSSIONS

Estimation of dry fodder availability

The potential dry matter availability of dry fodder in all the districts of Andhra Pradesh was presented in Table 4. The dry matter availability from dry fodder was estimated from the crop residues (coarse straw, fine straw, and leguminous straw) and concentrates. The total dry matter estimated from the crop residues was 24.46 million tonnes (Table 4). Within the crop residues, the fine straw consisting of paddy and wheat accounted for the major share (>65%) while coarse straw (27.68%) from maize, jowar, bajra, ragi, minor millets, and sugarcane tops and leguminous straw from pulses and groundnut accounted for a minor share (13.8%). Among different districts, West Godavari contributed the highest percentage followed by Guntur, Krishna, East Godavari, Nellore, Kurnool, and Srikakulam. These 7 districts shared more than half of the total dry fodder production of the state.

Estimation of green fodder availability

The total green fodder production in the state on a dry matter basis was estimated at 5.32 million tones (Table 5). Among different districts, Kurnool produced 11.04 per cent, followed by Anantapuram (10.90%), Prakasam (10.47%), East Godavari (9.08%), and Chittoor (8.82%) of green fodder of the state. These five districts produced more than 45.00 per cent of the green fodder in the state.

Estimation of concentrate availability

The total concentrates available in the state on a dry matter basis was estimated at 3.34 million tonnes The availability of concentrates on a dry matter basis was

Table 3. Green fodder yield for land use classification

Land use category	Green fodder (tonnes / ha / year)
Gross cropped area	1.6
Forests	1.5
Permanent pastures	5.0
Cultivable wasteland	1.0
Current fallows	1.0
Other fallows	1.0
Miscellaneous tree crops	1.0

shown in (Table 6). The byproducts like oil cakes, brans, and chunnies constituted the major portion, while grains constituted a small fraction of the concentrates. Within the concentrates, grains constitute 13.90 per cent, Bran and chunni constitute 32.24 per cent and oilcakes accounted for 64.9 per cent. District-wise analysis showed that East Godavari accounted for highest percentage as the production is more followed by West Godavari and Guntur in state concentrate production.

Estimation of Ruminant livestock units

Total ruminant livestock units (RLU) in the state were 9.24 million, buffaloes followed by cattle, sheep, and goats. Anantapuram district had highest RLU followed by Prakasam, Kurnool, Kadapa and Nellore of the state. The maximum number of cattle were in Kurnool, buffaloes in Prakasam, sheep and goats in the Anantapuram district in the state.

Feed and fodder demand and supply:

On the dry matter basis, the annual demand for feed and fodders based on RLU and per unit intake was estimated to be 23.61 million tonnes (Table 8). There is wide inter-district variability in demand for feed due to the difference in the number of RLU. The highest dry matter requirement was in the Anantapuram district followed by Prakasam, Kurnool, Kadapa, and Guntur as these districts have a higher population of animals. The supply of feed and fodders on a dry matter basis was a tune of 33.13 million tonnes and it was excess up to a tune of 9.52 million tonnes (40.35%) against the requirement of the state. The contribution of dry fodder towards overall dry matter was 73.82 per cent and green fodder and concentrate share 16.07 per cent and 10.10 per cent of total dry matter available in the state. The maximum availability of feed and fodder was in the West Godavari district followed by Guntur, East Godavari, Krishna and Kurnool, as these districts have higher production and more area for crops in comparison to other districts of the state. It was found that the four districts such as Visakhapatnam (-23.58%), Prakasam (-25.80%), Kadapa (-44.13%) and Anantapuram (-31.29%) were deficient in dry matter as compared to the requirement out of 13 districts. The excess feed and fodder were found in West Godavari (192.06%) followed by Krishna (131.03%), East Godavari (114.72%), Guntur (105.10%) and East Godavari (154.25%) as compared to their requirements. On average, potential dry matter availability was 9.82 kg RLU^{-1} day^{-1} as against the requirement (7 kg) in the state. The district-wise analysis revealed that maximum dry matter per day was available to each ruminant livestock unit in West Godavari (20.44 kg) and the minimum was in Kurnool (3.9 kg).

POLICY IMPLICATIONS

For further growth in the Animal husbandry sector in Andhra Pradesh, it is essential that the policymakers, planners, and researchers have to focus their attention on the following aspects while formulating future policies.

- Enhancing farm-level economy by feed cost reduction to restore confidence amongst the dairy farmers.
- Popularization of simple and cost-effective technologies like a chafing of green straw, urea ammoniation of stores, and enrichment strategic supplementation of macro and micronutrients could help in further efficient utilization of feed resources.
- Participatory rural appraisal (PRA) technique for transfer of technique and training to the rural users.
- Collection and post-harvest management of crop residues to fulfill the requirement of dry fodder.

Looking into the overall availability of livestock feed resources in the state, it has shown that presently there are sufficient feed resources available to meet the requirement of our livestock at least in quantitative terms. Nutritionally poor crop residues would continue to form the bulk of livestock feed for time to come and there is a need for efficient utilization of the existing

Table 4. District-wise availability of dry fodder from different crops in Andhra Pradesh

(Dry matter, 000T)

District	Coarse straw	Fine straw	Leguminous straw	Total dry fodder	Total DM
Srikakulam	454.05	1070.38	68.54	1592.98	1433.68
Vizianagaram	663.55	654.70	37.90	1356.15	1220.54
Visakhapatnam	469.81	524.99	15.80	1010.60	909.54
East Godavari	170.29	2778.44	34.87	2983.59	2685.24
West Godavari	916.46	3146.24	30.53	4093.23	3683.91
Krishna	502.16	2337.18	314.22	3153.56	2838.21
Guntur	1743.80	1620.82	245.67	3610.28	3249.25
Prakasam	279.34	588.66	368.60	1236.60	1112.94
Nellore	22.76	2392.54	142.27	2557.57	2301.82
Kadapa	74.08	288.35	341.71	704.14	633.73
Kurnool	826.63	780.50	789.76	2396.89	2157.20
Anantapuram	330.84	202.69	667.33	1200.86	1080.77
Chittoor	319.24	629.68	336.41	1285.33	1156.80
Total	**6773.01**	**17015.16**	**3393.62**	**27181.80**	**24463.62**

Table 5. District-wise availability of green fodder from different sources

(Dry matter, 000T)

District	Forest	GCA	Permanent pastures	Other sources	Total green fodder	Total DM
Srikakulam	103.5	628.8	5	81	818.30	204.58
Vizianagaram	178.5	496	25	148	847.50	211.88
Visakhapatnam	661.5	486.4	15	170	1332.90	333.23
East Godavari	699	987.2	105	143	1934.20	483.55
West Godavari	199.5	1009.6	55	88	1352.10	338.03
Krishna	114	1092.8	50	105	1361.80	340.45
Guntur	243	1203.2	60	175	1681.20	420.30
Prakasam	688.5	932.8	275	335	2231.30	557.83
Nellore	408	716.8	170	232	1526.80	381.70
Kadapa	751.5	582.4	45	281	1659.90	414.98
Kurnool	511.5	1563.2	15	264	2353.70	588.43
Anantapuram	295.5	1457.6	30	539	2322.10	580.53
Chittoor	678	694.4	165	342	1879.40	469.85
Total	**5532**	**11851.2**	**1015**	**2903**	**21301.20**	**5325.30**

Table 6. District wise dry matter availability from concentrates

(Dry matter, 000T)

District	Grains	Bran & Chuni	Oil cakes	Total concentrates	Total DM
Srikakulam	31.69	66.75	79.45	177.90	160.11
Vizianagaram	32.66	40.87	37.26	110.79	99.72
Visakhapatnam	11.13	32.67	70.40	114.20	102.78
East Godavari	48.20	171.57	577.34	797.11	717.40
West Godavari	81.96	193.93	379.01	654.90	589.41
Krishna	51.72	149.19	52.26	253.18	227.86
Guntur	79.36	103.47	148.11	330.95	297.85
Prakasam	18.33	42.35	22.55	83.24	74.91
Nellore	37.39	147.78	46.18	231.35	208.22
Kadapa	6.33	21.91	46.13	74.36	66.93
Kurnool	40.33	56.37	366.35	463.05	416.75
Anantapuram	15.72	13.76	224.21	253.69	228.32
Chittoor	11.32	39.28	125.35	175.96	158.36
Total	**466.15**	**1079.92**	**2174.62**	**3720.68**	**3348.62**

Table 7. Supply, demand, and gap in livestock feed and fodder among different districts of Andhra Pradesh

(Dry matter, 000T)

District	RLU	Dry matter required	Dry matter available	Difference	Gap (%) surplus/deficit
Srikakulam	458823.65	1172.29	1798.37	626.08	53.41
Vizianagaram	446261.66	1140.20	1532.14	391.94	34.37
Visakhapatnam	689150.47	1760.78	1345.55	-415.23	-23.58
East Godavari	708376.72	1809.90	3886.19	2076.29	114.72
West Godavari	617976.13	1578.93	4611.35	3032.42	192.06
Krishna	577105.48	1474.50	3406.52	1932.02	131.03
Guntur	757077.22	1934.33	3967.4	2033.07	105.10
Prakasam	920845.11	2352.76	1745.68	-607.08	-25.80
Nellore	743904.71	1900.68	2891.74	991.06	52.14
Kadapa	781525.31	1996.80	1115.64	-881.16	-44.13
Kurnool	812924.78	2077.02	3162.38	1085.36	52.26
Anantapuram	1076318.92	2749.99	1889.62	-860.37	-31.29
Chittoor	650883.91	1663.01	1785.01	122	7.34
Total	**9241174.04**	**23611.20**	**33137.54**	**9526.34**	**40.35**

feed resources and to enhance the nutritive value of crop residues through suitable technologies. From the overall situation, it was suggested that the scope of increasing the contribution of feed resources is possible by bringing about changes in the cropping pattern. Crop residues that form the major component can be treated suitably to enhance their nutritional value.

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SOIL STRUCTURE AND ORGANIC CARBON STABILITY OF RAINFED *ALFISOLS* UNDER LONG-TERM APPLICATION OF MANURE AND FERTILIZERS

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ABSTRACT

An experiment on long-term application of fertilizers and manure was initiated in the year 1981 during *kharif* season at Regional Agricultural Research Station, Tirupati, Andhra Pradesh, India in rainfed *Alfisols* under groundnut monocropping system. The same experiment was used for the present investigation during *kharif,* 2021 season, to study the influence of long-term application of fertilizers and manure on soil aggregate and aggregate associated carbon. The experiment has eleven treatments each replicated four times in a randomized block design. The results revealed that the soil aggregate fractions under long-term application of FYM @ 5 t ha^{-1} (T_2) and treatmental combinations *viz.,* NPK+gypsum+$ZnSO_4$ (T_{11}), NPK + lime (T_{10}), NPK + gypsum (T_9) and NPK (T_8) recorded significantly higher in large and small macro-aggregates fractions compared to control and single nutrient fertilizers, which recorded highest in micro-aggregates fractions. The aggregate associated-C recorded significantly higher in large macro-aggregates compared to small macro and micro-aggregate fractions in both the soil layers. However, the aggregate associated-C was higher in surface layer compared to sub-surface layer.

KEYWORDS: Aggregates**,** *Alfisols*, long-term, treatment combinations.

INTRODUCTION

Long-term fertilizer experiments plays an important role in understanding the changes in physical and physico-chemical properties and productivity of the crops The decline in soil fertility due to the imbalanced fertilizer use has been recognized as one of the most important factors limiting crop yield (Nambiar and Abrol, 1989). This LTFE also provides valuable information on impact of continuous use of fertilizers with varying combination of organics and inorganics on soil physical and chemical properties and became good platform for monitoring the changes. Inorganic and organic fertilizers are the important factors for maintenance and improvement of soil fertility and aggregation. Application of inorganic fertilizers results in higher soil organic matter (SOM) accumulation and biological activity due to increased plant biomass production and organic matter returns to soil in the form of decaying roots, litter and crop residues. Addition of SOM enhances soil organic carbon (SOC) content, which is an important indicator of soil quality and crop productivity. The combined application of inorganic fertilizers and organic manures could affects the soil physical properties such as soil aggregation, aggregate stability, water holding capacity, porosity, infiltration rate, hydraulic conductivity and bulk density directly or indirectly due to increased SOC content.

Sustaining the soil quality is the most appropriate method to ensure sufficient in food production in any agro-ecosystem. Hence, the maintenance of soil organic carbon pool is considered essential for long-term sustainable productivity. Soil organic matter being a store house of all essential plant nutrients, it plays a pivotal role in crop production. The soil organic carbon together with physical properties has been proposed as indicator of soil quality (Doran and Parkin, 1994). The important indicators of soil quality in relation to soil organic carbon content are mean weight diameter (MWD) of aggregates, available water holding capacity, cation exchange capacity (CEC) and bulk density (BD). The relative importance of these indicators varies among different soils and therefore, site-specific information is needed on these properties for quantitative assessment of soil quality (Lai *et al.* 1998). In view of the utmost significance of soil organic carbon in determining soil quality, adoption of judicious management practices to restore and upgrade soil organic carbon pool is essential

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MATERIAL AND METHODS

Study area and climate

The present study was carried out as part of the long-term experiment during *kharif*, 2021 on red sandy loam (*Haplustalf*) soils at Regional Agricultural Research Station, Acharya N.G Ranga Agricultural University, Tirupati, Chittoor district, Andhra Pradesh. The experiment was laid out in randomized block design with eleven treatments and four replications. The treatments includes T_1 : control (no manure and fertilizers), T_2 : Farm yard manure @ 5 t ha^{-1} (once in 3 years), T_3 : 20 kg nitrogen (N) ha^{-1}, T_4 : 10 kg phosphorus (P) ha^{-1}, T_5 : 25 kg potassium (K) ha^{-1}, T_6 : 250 kg gypsum ha^{-1}, T_7 : 20 kg N + 10 kg P ha^{-1}, T_8 : 20 kg N + 10 kg P + 25 kg K ha^{-1}, T_9 : 20 kg N + 10 kg P + 25 kg K + 250 kg gypsum ha^{-1}, T_{10} : 20 kg N + 10 kg P + 25 kg K + 100 kg lime ha^{-1}, T_{11} : 20 kg N + 10 kg P + 25 kg K + 250 kg gypsum + 25 kg ha^{-1} zinc sulphate (once in 3 years). The nutrients NPK were applied through the fertilizers like urea, single super phosphate and muriate of potash. The farmyard manure and $ZnSO_4$ were not applied in this *kharif* season. The test crop was groundnut and variety selected was Dharani. The crop was sown on 09-07-2021 and harvested on 23-10-2021. The weekly mean maximum temperature during the crop period ranged from 31.6 to 35.6°C with an average of 33.5°C while the weekly mean minimum temperature ranged between 22.6 to 25.7°C with an average of 24.5°C. The weekly mean relative humidity ranged between 57.4 to 79.1 per cent with an average of 68.8 per cent. The weekly mean sunshine hours during the crop period ranged between 1.9 to 8.0 h day^{-1} with an average of 4.71 h day^{-1}. The weekly mean evaporation ranged between 2.7 to 4.8 mm day^{-1} with an average of 3.8 mm day^{-1}. A total rainfall of 764.6 mm was received in 42 rainy days during the crop growth period.

Soil sampling and laboratory analysis

Soil samples were collected from 0-15 and 15-30 cm depth after harvest of the crop. While collecting the samples two pits were dug in each plot with the help of spade. The two soil samples were mixed separately depth wise, dried under shade and labelled. The soil samples so collected were analyzed for physical and physico-chemical properties by using standard procedures. Aggregate analysis was done by wet sieving method (Yoder, 1936) for two depths *i.e.* 0–15 cm and 15–30 cm. The Yoder apparatus have a vertical stroke of 45 mm, and was operated for 10 min at a speed of 28 to 32 strokes per min. A bunch of sieves comprising of six sieves of various breadths going from 5 mm, 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm secured to a holder, through a distance of 3.18 cm arranged in assembly at a descending order. The soil sample (5 to 8 mm size) was kept on the top of 5 mm sieve and allowed to wet in water for 10 min. The sieves were then swayed vertically and rhythmically, so that water was made to flow up and down throughout the screens and the assemblage of aggregates. At the end of 10 minutes period, the nest of sieves was removed carefully from the water, and aggregates retained on the each sieve was back washed into a pre-weighed beakers and dried in oven at 105 °C for 24 hrs. After drying, weight of aggregate retained on each sieve was weighed.

The organic carbon content of the soil aggregates were estimated by the method given by Walkley and Black wet oxidation (1934) as outlined by Jackson (1973) and was expressed in percentage.

RESULTS AND DISCUSSION

Soil aggregation

Soil aggregate fractions under long-term application of FYM @ 5 t ha^{-1} (T_2) and treatmental combinations *viz.,* NPK + gypsum + $ZnSO_4$ (T_{11}), NPK + lime (T_{10}) and NPK + gypsum (T_9) recorded significantly higher in large and small macro-aggregates fractions compared to control and single nutrient fertilizers, which recorded highest in micro-aggregates fractions. In surface layer (0-15 cm), the micro-aggregates (<0.25 mm) ranged from 19.93 to 31.03 per cent with the mean of 24.92 per cent . The highest was observed in control (T_1) (31.03%) and which was on par with the treatment P alone (T_4) (27.97%), N alone treated plot (T_3) (27.80%) and NPK treated plot (T_8) (26.97%). Whereas, the lowest was observed in FYM alone treated plot (T_2) (19.93%). The small macro-aggregates (2-0.25 mm) ranged from 55.73 to 62.77 per cent with the mean of 59.01 per cent. The highest was observed in NPK + gypsum (T_9) (62.77%) and which was on par with FYM alone (T_2) (62.27%), NP (T_7) (61.60%) and NPK + lime (T_{10}) (60.23%). Whereas, the lowest was observed in NPK + gypsum + $ZnSO_4$ (T_{11}) (55.73%). The large macro-aggregates (>2

Table 1. Effect of long-term application of manure and fertilizer on soil aggregate proportion mass in aggregate class (%) at surface and sub-surface layers after harvest

Treatments	Micro-aggregate (< 0.25 mm)		Small macro-aggregate (2-0.25 mm)		Large macro-aggregate (> 2 mm)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1 : Control	31.03	25.20	56.13	58.03	12.83	16.77
T_2 : FYM @ 5 t ha^{-1} (once in 3 years)	19.93	20.00	62.27	59.67	17.80	20.33
T_3 : N @ 20 kg ha^{-1}	27.80	22.80	57.47	59.60	14.73	17.60
T_4 : P @ 10 kg ha^{-1}	27.97	25.30	57.43	55.03	14.60	19.67
T_5 : K @ 25 kg ha^{-1}	25.03	25.73	60.03	57.30	14.93	16.97
T_6 : Gypsum @ 250 kg ha^{-1}	25.03	26.07	59.17	54.77	15.80	19.17
T_7 : NP	22.40	22.53	61.60	58.30	16.00	19.17
T_8 : NPK	26.97	28.13	56.30	52.83	16.73	19.03
T_9 : NPK + gypsum	20.63	20.50	62.77	59.97	16.60	19.53
T_{10} : NPK + lime @ 100 kg ha^{-1}	22.17	22.63	60.23	56.87	17.60	20.50
T_{11} : NPK + gypsum + $ZnSO_4$ @ 25 kg ha^{-1}	25.17	21.80	55.73	57.80	19.10	20.40
Mean	**24.92**	**23.70**	**59.01**	**57.28**	**16.07**	**19.01**
SEm±	**1.77**	**1.26**	**1.51**	**1.37**	**1.07**	**0.91**
CD (P=0.05)	**5.25**	**3.73**	**4.47**	**4.06**	**3.17**	**NS**

mm) ranged from 12.83 to 19.10 per cent with the mean of 16.07 per cent. The highest was observed in NPK + gypsum + $ZnSO_4$ (T_{11}) (19.10%) and which was on par with FYM alone (T_2) (17.80%), NPK + lime (T_{10}) (17.60%) and NPK (T_8) (16.73), whereas lowest was observed in control (T_1) (12.83%).

In sub-surface layer (15-30 cm), the micro-aggregates (<0.25 mm) ranged from 20.00 to 28.13 per cent with the mean of 23.70 per cent. The highest was observed in NPK (T_8) (28.13 %) and which was on par with gypsum (T_6) (26.07%), K (T_5) (25.73%) and P treated plots (T_4) (25.30%), whereas lowest was observed in FYM alone treated plot (T_2) (20.00%). The small macro-aggregates (2-0.25 mm) ranged from 52.83 to 59.97 per cent with the mean of 57.28 per cent. The highest was observed in NPK + gypsum treatment (T_9) (59.97%) and which was on par with FYM alone (T_2) (59.67%), N alone (T_3) (59.60%) and NP (T_7) (58.30%) treated plots, whereas lowest was observed in NPK (T_8) (52.83%) treatment. The large macro-aggregates (>2 mm) ranged from 16.77 to 20.50 per cent with the mean of 19.01 per cent. The highest was observed in NPK + lime (T_{10}) (20.50%) followed by NPK + gypsum + $ZnSO_4$ (T_{11}) (20.40%) and FYM (T_2) (20.33%), treated plots whereas lowest was observed in control (T_1) (16.77%).

The results revealed that, among the soil aggregate fractions (%) small macro-aggregates are higher compared to large macro and micro-aggregates in both surface and sub-surface layers. The data revealed that aggregate fraction of size >0.25 mm were in higher in treatments received with FYM alone, NPK + lime, NPK + gypsum and NPK+gypsum+$ZnSO_4$ treatments compared to other treatments. This might be due to the increased root biomass which indirectly helped in improvement of large and small macro-aggregates stabilization in aforesaid treatments. Whereas the aggregate fraction of <0.25 mm size was significantly higher in treatment received with only inorganic fertilizers and control treatments compared to the other treatments. Interestingly, microaggregates fraction was decreased with the application of FYM alone in both surface and sub-surface soils. This indicates that higher formation of larger aggregates with the supplimentation of organic matter. The present results are in agreement with the findings of Chakraborty *et al.* (2010) who reported that organic manure incorporation increased soil macro-aggregate proportion. The higher percentage of aggregates <0.25 mm was evidenced under single nutrient treatments *viz.,* N, P, K and control in surface and sub-surface layers, which might be ascribed to comparatively low level of carbonates and organic matter. These results are in agreement with the findings of Manna *et al.* (2007) and Ghosh *et al.* (2010). The lower percentage of large macro-aggregates (>2 mm) in control plot in surface (12.83%) and sub-surface (16.77%) layers, respectively, might be due to comparatively lesser binding materials compared to other treatments. Similar findings were reported by Aziz and Karim (2016).

Aggregate association carbon

In surface layer (0-15 cm), the aggregate associated-C in micro-aggregates (<0.25 mm) ranged from 2.47 to 4.18 g kg^{-1} with the mean of 3.06 g kg^{-1}. The highest was observed in gypsum alone treated plot (T_6) (4.18 g kg^{-1}) and the lowest was observed in NP (T_7) (2.47 g kg^{-1}) treatment. The aggregate associated-C in small macro-aggregates (2-0.25 mm) ranged from 2.80 to 3.95 g kg^{-1} with the mean of 3.22 g kg^{-1}. The highest was observed in FYM alone (T_2) (3.95 g kg^{-1}) and lowest was observed in NP (T_7) (2.80 g kg^{-1}) treated plots. And the aggregate associated-C in large macro-aggregates (>2 mm) ranged from 3.36 to 5.01 g kg^{-1} with the mean of 4.10 g kg^{-1}. The highest was observed in FYM alone treated plot (T_2) (5.01 g kg^{-1}) and lowest was observed in control (T_1) (2.80 g kg^{-1}). In sub-surface layer (15-30 cm), the aggregate associated-C in micro-aggregates (<0.25 mm) ranged from 2.42 to 3.48 g kg^{-1} with the mean of 3.01 g kg^{-1}. The highest was observed in FYM alone (T_2) (3.48 g kg^{-1}) and lowest was observed in NP (T_7) (2.42 g kg^{-1}) treatments. The aggregate associated-C in small macro-aggregates (2-0.25 mm) ranged from 2.68 to 3.58 g kg^{-1} with the mean of 3.05 g kg^{-1}. The highest was observed in FYM alone treatment (T_2) (3.58 g kg^{-1}) and lowest was observed in control (T_1) (2.68 g kg^{-1}). And the aggregate associated-C in large macro-aggregates (>2 mm) ranged from 3.02 to 4.12 g kg^{-1} with the mean of 3.41 g kg^{-1}. The highest was observed in FYM alone treatment (T_2) (4.12 g kg^{-1}) and lowest was observed in control (T_1) (3.02 g kg^{-1}).

The results indicated that SOC was significantly higher in large macro-aggregates when compared to small macro and micro-aggregates. The higher SOC within large macro-aggregates might be due to carbon associated with the formation of microaggregates inside

Table 2. Effect of long-term application of manure and fertilizers on aggregate associated-C (g kg^{-1}) at surface and sub-surface layers after harvest

Treatments	Micro-aggregate (< 0.25 mm)		Small macro-aggregate (2-0.25 mm)		Large macro-aggregate (> 2 mm)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1 : Control	2.87	2.98	2.86	2.68	3.36	3.02
T_2 : FYM @ 5 t ha^{-1} (once in 3 years)	2.77	3.48	3.95	3.58	5.01	4.12
T_3 : N @ 20 kg ha^{-1}	2.70	2.72	2.91	2.83	3.69	3.24
T_4 : P @ 10 kg ha^{-1}	3.10	2.51	2.91	3.04	3.54	3.53
T_5 : K @ 25 kg ha^{-1}	3.23	3.28	2.87	2.86	3.91	3.22
T_6 : Gypsum @ 250 kg ha^{-1}	4.18	3.05	3.61	3.33	4.17	3.65
T_7 : NP	2.47	2.42	2.80	2.82	3.70	3.04
T_8 : NPK	2.60	3.33	3.81	3.28	4.45	3.69
T_9 : NPK + gypsum	3.25	3.15	3.03	2.80	4.52	3.21
T_{10} : NPK + lime @ 100 kg ha^{-1}	3.37	3.10	3.27	3.08	4.67	3.47
T_{11} : NPK + gypsum + $ZnSO_4$ @ 25 kg ha^{-1}	3.17	2.98	3.10	3.27	4.04	3.32
Mean	**3.06**	**3.01**	**3.22**	**3.05**	**4.10**	**3.41**
SEm±	**0.18**	**0.22**	**0.11**	**0.08**	**0.15**	**0.14**
CD (P=0.05)	**0.53**	**0.66**	**0.33**	**0.24**	**0.45**	**0.42**

macroaggregates, which better protects SOC from being lost due to various soil physico-chemical properties. Even though microaggregate associated C concentration is low, it is important for protection of total SOC in soils having lower turnover rates. These results are in confirmity with the findings of Yu *et al.* (2012) and Liang *et al.* (2012) who recorded that aggregate formation was associated with increased carbon storage in aggregate fractions >53 µm than in the silt and clay fraction (<53 µm). The highest aggregate associated-C was found in the case of FYM alone treated plot compared to other treatments, which might be due to FYM application provides different organic carbon compounds to soil directly and increased root biomass and returning large amounts of carbon to the soil indirectly. The lowest aggregate association-C was observed in single nutrient treatments like N, P, K and control in surface and sub-surface layers, might be due to less addition of organic matter thereby reduction in C accumulation in all aggregates fractions. The present results are in agreement with the findings of Zou *et al.* (2018) and Mohan *et al.* (2020). The aggregate associated-C content was decreased with decrease in aggregate size fractions. The results are similar to those of Li *et al.* (2020) who reported that the SOC content was decreased in <0.25 mm aggregates when compared to >0.25 mm aggregate sizes in 9 years long-term experiment. However, long-term amendment of manure significantly increased SOC in macro-aggregates. Similar results were also reported by Zhang *et al*. (2021) and Niu *et al*. (2022).

In conclusion, the present study indicated that long-term application of FYM @ 5 t ha^{-1} once in three years was very effective in increasing the soil physical, physio-chemical environment and increase in macro-aggregate fractions. The aggregate associated-C recorded significantly higher in large macro-aggregates compared to small macro and micro-aggregate fractions in both the soil layers. However, the aggregate associated-C was higher in surface layer compared to sub-surface layer. The study also revealed that balanced nutrition treatments *viz.,* NPK + gypsum + $ZnSO_4$, NPK + lime, NPK + gypsum and NPK were also equally effective in increasing macro-aggregate fractions. However, long-term application of FYM @ 5 t ha^{-1} or NPK + lime improved the soil structure, aggregate and organic carbon stability of rainfed *alfisols*. Whereas the long-term application of K fertilizers alone deteriorated the soil structure and organic carbon stability.

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