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Research article

MEDICATED PRICKLY PEAR (*OPUNTIA FICUS INDICA)*-THE NEW EMERGING AGRICULTURAL CROP IN ARID AND SEMI ARID REGIONS OF INDIA

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ABSTRACT: The present investigation deals with the development of agro-techniques *for Opuntia ficus indica* (Prickly pear)-OFI cultivation. Standardization and development of best spacing for opuntia plantation, fertilization imposition to achieve good fruit and biomass yield and alternatively fruit quality and biomass parameters was observed and concluded as the better agro-technique among the all imposed treatments. The effect of different spacing and fertilizers composition treatment on cladode yield, fruit yield, harvesting index, stem area index (SAI), Total soluble solids (TSS), Titrable acidity and Ascorbic acid (Vit-C). Correlation studies of treatments revealed that all the six characters of cladode yield, harvest index, Stem area index, TSS, TA and Vit-C exhibited non significant, positive correlation with fruit yield.

Key words: Replications, Spacing; Fertilizer, Prickly pear, TSS; TA, Vit-C, Harvest index, Stem area index, Yield

INTRODUCTION

The *Opuntia Ficus Indica (L) Mill* is a Xerophyte popularly known as Opuntia Plant or Cactus Plant or Prickly pear plant in English, Nopal in Spanish. Prickly pear or prickly pear (Tuna in Spanish) means the fruit and cladode means the stems (in Spanish *nopalito* refers to the tender cladode and *penca* to the fleshy mature cladodes or 'leaves'). Scientifically opuntia is belongs to Kingdom: *Plantae*, Order: *Caryophyllales*, Family: *Cactaceae*, Genus: *Opuntia*, Species: *Opuntia Ficus Indica*. The *Opuntia* species is known by different names in the various countries where it is found. The original name, in the Náhuatl language, is *nochtli*. Notwithstanding, the Spanish renamed the plant *chumbera* and the fruit *higo de las Indias* (Indian fig), which today is known as *higo chumbo* (chumbo fig). In Italy it is known as *fico d'India*, in France as *figue de Barbarie* and in Australia, South Africa and the United States, as prickly pear. This is slowly evolving into the name prickly pear, to reduce the negative connotation of the word 'prickly' (meaning 'with spines'). In Israel it is known as *sabras*, meaning 'spiny outside but sweet inside'. In Eritrea and Ethiopia it is called *beles*. (FAO, Rome, 2013).

Almost 300 species of the genus *Opuntia* are known but, so far, only 10 to 12 species have been utilized for their fruit, tender leaves (cladodes), forage or cochineal for colorant production. The most cultivated species for fruit production are: *Opuntia ficus-indica, Opuntia amyclae, Opuntia xoconostle, Opuntia megacantha* and *Opuntia streptacantha.* Wild species include *Opuntia hyptiacantha*, *Opuntia leucotricha* and *Opuntia robusta.* The most widely cultivated species throughout the world is *Opuntia ficus-indica*. It is the only *Opuntia* cultivated in the Mediterranean basin, where it is used for a variety of purposes (Uzun, 1996).

Functional compounds are those that help prevent disease. The fruit and cladodes of prickly pear provide interesting sources of functional compounds, including fiber, hydrocolloids (mucilage), pigments (betalains and carotenoids), minerals, (calcium and potassium) and vitamins with antioxidant properties, such as vitamin C. These compounds are valued for their contribution to a healthy diet and also as ingredients for designing new foods (Sáenz, 2004). The contents of these compounds differ in fruits and cladodes. For instance, the pulp of the fruit is richer in vitamin C, while cladodes are higher in fibre. Pigments are found mainly in the fruit, and both betalains and carotenoids are present in the peel and pulp of various ecotypes. These compounds can be included in a new range of foods known as functional foods, which are as foods or beverages that provide physiological benefits. They enhance health, help to prevent or treat disease and/or improve physical or mental performance with the addition of one or more functional ingredients or using appropriate biotechnologies (Sloan, 2002).

Most of the sugars present in the prickly pear fruit are reducing types, with around 53 percent glucose and the remainder fructose (Russel and Felker,1987; Sawaya *et al.*, 1983; Sepúlveda and Sáenz,1990; Kuti and Galloway, 1994; Rodríguez *et al.*1996). The contents of protein (0.21–1.6 g [100 g]$^{-1}$), fat (0.09–0.7 g [100 g]$^{-1}$), fibre (0.02–3.15 g [100 g]$^{-1}$) and ash (0.4–1.0 g [100 g]$^{-1}$) are similar to other fruits (Askar and El Samahy, 1981; Pimienta, 1990; Sawaya *et al.*, 1983; Sepúlveda and Sáenz, 1990; Rodríguez *et al.*, 1996; Muñoz de Chávez *et al.*, 1995). Prickly pear has a relatively high level of serine, g-amino butyric acid, glutamine, proline, arginine and histidine and also contains methionine (Askar and El-Samahy, 1981). The fruit has a high level of ascorbic acid, reaching values of 40 mg (100 g)$^{-1}$, which is higher than in apples, bananas, grapes and pears. The fruit is a good source of minerals, such as potassium (217 mg [100 g]$^{-1}$), and is low in sodium (0.6–1.19 mg [100 g]$^{-1}$), which is beneficial for people with kidney problems and hypertension (Sepúlveda and Sáenz, 1990; Rodríguez *et al.*,1996). It is also rich in calcium and phosphorus,with levels of 15.4–32.8 mg (100 g)-1 and 12.8–27.6 mg (100 g)-1 respectively (Sawaya *et al.*,1983; Sepúlveda and Sáenz, 1990).

To the best of our knowledge there are no commercial plantations and no definite varieties of prickly pear India. However some promising exotic prickly pear clones form Northern Mexico and Texas are being identified for low seed content, high TSS, betalain, ascorbic acid and extended storage life of fruits. In Texas trials, clones 1319 and 1321 from chili were promising as they had both low seed content and high sugar content. The clones 1282 and 1279 also had low seed content (2.2-2.3 g/ fruit) with highly desirable dark purple fruit. The clones 1452 and 1260 are the spineless red yellow fruited types from Mexico and Algeria respectively had good production with moderate TSS (12.6^0 brix), sufficient fruit size have immediate commercial potential (Cowan and Felker, 1998, Paris and Felker, 1997). Currently opuntia is growing in the wild and thus it must be cultivated if the benefits from the plant are sustained provided with supplement of improved agronomic and orchard management practices.

Keeping in view of the above said points, it is therefore taken up a research project entitled Evaluation of prickly pear cactus *(Opuntia ficus indica (L) Miller)* as an alternative crop in Rayalaseema region of A.P for Quality fruit production on dry land fields located at College of Food Science and Technology, Pulivendula, (Chinna rangapuram) YSR Kadapa District, A.P, India.

MATERIAL AND METHODS

Area selection for cultivation

A field experiment was conducted during 2010-2013 at College of Food Science and Technology, (ANGRAU), Pulivendula (Chinnarangapuram), YSR Kadapa (Dt), a representative area of semi arid region of Rayalaseema zone (A.P State, India) with an annual precipitation of 550 mm and soils of red sandy loams to evaluate the suitability of these areas for prickly pear *(Opuntia ficus indica)* cultivation on sound (profitable) basis for biomass (as fodder) and fruit(as industrial food) production.

Layout plan of Experimental Plot for cultivation:

The field experiment was laid out with three levels of spacing as main plots and five levels of the fertilizer doses as subplots including control of the following replicated thrice in factorial randomized block design.

Spacing treatments S1 (0.5m), S2 (0.75m) and S3 (1m) and

Fertilization treatments F0 (Control), F1 (FYM 20t/ha), F2 (50:30:40 kg N P K and FYM@20 t/ha), F3 (55:35:45 kg N P K and FYM@20 t/ha) and F4 (60:40:50 kg N P K and FYM@20 t/ha).

Morphological and Biochemical studies:

To measure the cladode yield, fruit yield, harvesting index, stem area index (SAI) Total soluble solids (TSS), Titrable acidity and Ascorbic acid (Vit-C).

RESULTS

The figure 1 showed the layout of plantation of OFI in agricultural field. The interaction treatments of spacing and fertilizers on cladode yield, fruit yield and harvest index tabulated in the Table.1. The interaction treatments S3F4, S3F3, S3F2 and S3F0, as also S2F4, S2F3, and S2F2 were on pair with each other in respect of per plot cladode yield. Similarly the cladode yield per plot between the interaction treatments S2F2, S3F0, S2F1 and S2F0 and also between S2F0, S1F4, S1F2 and S1F1 were at par with each other, the interaction effects between the spacing and fertilizer doses were also significant at both 5% and 1% level for fruit yield.

Table-1: Effects of levels of spacing and fertilizer dose on cladode Yield, Fruit yield and harvest index

Treatments	**Cladode yield (a)**		**Fruit yield (b)**		**Harvest index(c)**
Spacing	**Per plot (kg)**	**Per hectare (tonnes)**	**Per plot (kg)**	**Per hectare (tonnes)**	**Fruit yield/Biomass ie, cladode yield**
S1	14.69	29.38	1.77	3.54	0.120
S2	19.53*	26.07	2.34*	3.12	0.120
S3	24.13**	24.17	2.69**	2.69	0.111
F test	Sig		Sig		N.S
C.D(P=0.05)	4.58		0.33		
(P=0.01)	9.43		0.51		
Fertilizer dose					
F0	16.03	21.97	1.58	2.17	0.099
F1	19.63**	26.67	2.06*	2.83	0.106
F2	20.26**	27.60	2.35**	3.23	0.117
F3	20.53**	27.96	2.55**	3.50	0.125
F4	20.91**	28.50	2.79**	3.85	0.135
F test	Sig		Sig		Sig
C.D(P=0.05)	2.35		0.40		0.020
(P=0.01)	3.66		0.62		0.029
Spacing × Fertilizer dose Interaction					
S1 F0	12.52	25.04	1.23	2.46	0.098
S1 F1	14.59**	29.18	1.64**	3.28	0.112
S1 F2	15.26**	30.52	1.80**	3.60	0.118
S1 F3	15.36**	30.72	1.94**	3.88	0.126
S1 F4	15.71**	31.42	2.24**	4.48	0.143
S2 F0	15.86**	21.15	1.62**	2.16	0.102
S2 F1	19.61**	26.15	2.05**	2.73	0.104
S2 F2	20.29**	27.05	2.48**	3.31	0.122
S2 F3	20.78**	27.71	2.68**	3.57	0.129
S2 F4	21.22**	28.29	2.89**	3.85	0.136
S3 F0	19.71**	19.71	1.89**	1.89	0.096
S3 F1	24.68**	24.68	2.49**	2.49	0.101
S3 F2	25.22**	25.22	2.77**	2.77	0.110
S3 F3	25.45**	25.45	3.06**	3.06	0.120
S3 F4	25.79**	25.79	3.24**	3.24	0.127
F test	Sig		Sig		Sig
C.D(P=0.05)	1.06		0.20		0.028
(P=0.01)	1.57		0.30		0.041

- * and** = Significant at 5 and1 percent, respectively. NS= Not Significant.

S1=1 ×0.5m (20,000 plants/ha), S2=1× 0.75m (13,333 plants/ha), **S3**=1 ×1m (10,000 plants/ha)
F0=Control, F1-FYM 20 t/ha, F2-50:30:40 kg NPK+FYM 20 t/ha, **F3**-55:35:45 kg NPK kg+ FYM 20 t/ha, **F4**=60:40:50 kg NPK+FYM20 t/ha
Note: FYM= Farm Yard Manure, N= Nitrogen, P= Phosphorus, K= Potassium

Table-2: Effect of levels of spacing and fertilizer dose on Stem Area Index (SAI), Total soluble solids (TSS), Titratable acidity and Ascorbic acid (Vitamin C)

Treatments	Steam Area Index(SAI) (a)	Total soluble solids (TSS)0Brix (b)	Titratable acidity% (c)	Ascorbic acid mg/100gm of fruit pulp (d)
Spacing				
S1	0.313	14.4	0.09	27.4
S2	0.389*	14.8	0.11*	31.8*
S3	0.518*	15.7**	0.12**	33.2**
F test	Sig	Sig	Sig	Sig
C.D(P=0.05)	0.164	0.85	0.02	4.3
(P=0.01)	---	1.25	0.03	5.7
Fertilizer dose				
F0	0.335	13.9	0.05	22.0
F1	0.375	14.4	0.07	26.7
F2	0.411	15.3*	0.12**	31.7*
F3	0.432	15.5*	0.13**	35.7*
F4	0.479*	15.9**	0.17**	38.0**
F test	Sig	Sig	Sig	Sig
C.D(P=0.05)	0.146	1.22	0.04	8.9
(P=0.01)	----	1.89	0.06	13.9
Spacing × Fertilizer dose Interaction				
S1 F0	0.251	13.4	0.03	21.0
S1 F1	0.278	14.0	0.05	25.0
S1 F2	0.308	14.4	0.08**	29.0
S1 F3	0.332	14.8	0.12**	33.0*
S1 F4	0.392	15.3	0.15**	29.0
S2 F0	0.336	13.9	0.05	23.0
S2 F1	0.378	14.3	0.07**	26.0
S2 F2	0.396	14.8	0.11**	32.0*
S2 F3	0.396	15.3	0.13**	36.0**
S2 F4	0.440	15.7	0.17**	42.0**
S3 F0	0.414	14.6	0.06*	22.0
S3 F1	0.468*	15.1	0.08**	29.0
S3 F2	0.530*	15.8	0.13**	34.0*
S3 F3	0.572*	16.4	0.15**	38.0**
S3 F4	0.604**	16.8	0.19**	43.0**
F test	Sig	NS	Sig	Sig
C.D(P=0.05)	0.225		0.03	10.0
(P=0.01)	0.326		0.04	15.0

* and** = Significant at 5 and1 percent, respectively. NS= Not Significant.
S1=1 ×0.5m (20,000 plants/ha), S2=1× 0.75m (13,333 plants/ha), S3=1 ×1m (10,000 plants/ha)
F0=Control, F1-FYM 20 t/ha, F2-50:30:40 kg NPK+FYM 20 t/ha, F3-55:35:45 kg NPK kg+FYM 20 t/ha, F4=60:40:50 kg NPK+FYM20 t/ha.
Note: FYM= Farm Yard Manure, N= Nitrogen, P= Phosphorus, K= Potassium

The interaction treatments S3F4, S2F4, S3F2 and S2 F3 recorded significantly high fruit yield per plot (2.23, 3.06, 2.89, 2.77 and 2.68 kg respectively) and all these treatments except S3F2and S2F3 were significantly superior over the rest of the interaction treatments, but they were at par with each other. The treatments S2F2 (2.77 kg), S2F3 (2.68 kg), S3F1 (3.49 kg), S2F2 (2.48 kg) and S1F4 (2.24 kg) were also on par with each other in per plot fruit yield at 1% level, but significantly superior over S2F1 (2.05 kg), S3F0 (1.89 kg), S1F2 (1.80 kg), S1F1 (1.64 kg), S2F0 (1.62 kg) and S1F0 (1.23 kg).

Similarly the interaction treatments S3F1, S2F2, S1F4, S2F1 and S3F0 were also at par with each other, but significantly superior over S1F2, S1F1, S2F0 and S1F0. These treatments (except S3F1 and S2F2) were also at par with each other along with other treatments S1F2, S1F1 and S2F0, but significantly superior over S1F0. The interaction effects between the spacing and fertilizer doses were significant at 1% level for harvest index.
The interaction treatments S1F4 (0.143), S2F4 (0.136), S2F3 (0.129), S3F4 (0.127), S1F3 (0.126), S1F2 (0.122), S3S3 (0.120) and S1F2 (0.118) were however on par with each other in harvest index, but significantly superior over the rest of the interaction treatments. Treatments (except S1F4 and S2 F4) were also at par with S1F1 (0.112), S3F2 (0.110), S2F1 (0.104) S2F0 (0.102) and S3F1 (0.101). The interaction treatment S2F3 was also significantly superior over S1F0 (0.098) and S3F0 (0.096). The results of the interaction effects between the spacing and fertilizer doses treatments on SAI revealed significant differences between the levels of spacing and fertilizer doses at 1% also. The interaction treatments S3S4 (0.63) and S3F3 (0.572) recorded significantly superior SAI over the other treatments except S3S2 (0.530) S3F1 (0.468) and S2F4 (0.44) which were at par with each in SAI. The other interaction treatments were also at par with each other except S3F2 (0.530) which was significantly superior over these treatments in SAI. Significantly high SAI was recorded by the wider spacing treatment S3-1.0 m2 (i.e Low density planting) interacting with higher doses of fertilizer treatments F4 (0.640), F3 (0.572), F2 (0.530), F1 (0.468) followed by S2-0.75 m2 with F4 (0.440), S2F3 (0.396), S2F2 (0.396) and S1F4 (0.392), S2F1 (0.378), S1F3 (0.332) and S1F1 (0.278). The control fertilizer treatment F0 also recorded superior SAI interacting with S3 (0.414), S2 (0.336) comparatively than S1 (0.251) which was the least in SAI among all the interaction treatments. The results revealed an increased trend of TSS with increasing levels of spacing and fertilizer doses. The highest TSS of 16.80% was witnessed with S3-F4 treatment followed by S3F3 (16.40%), S3F2 (15.80%) and S3F1 (15.10%). The Table 2 presented the Effect of levels of spacing and fertilizer dose on Stem Area Index (SAI), Total soluble solids (TSS), Titratable acidity and Ascorbic acid (Vitamin C).

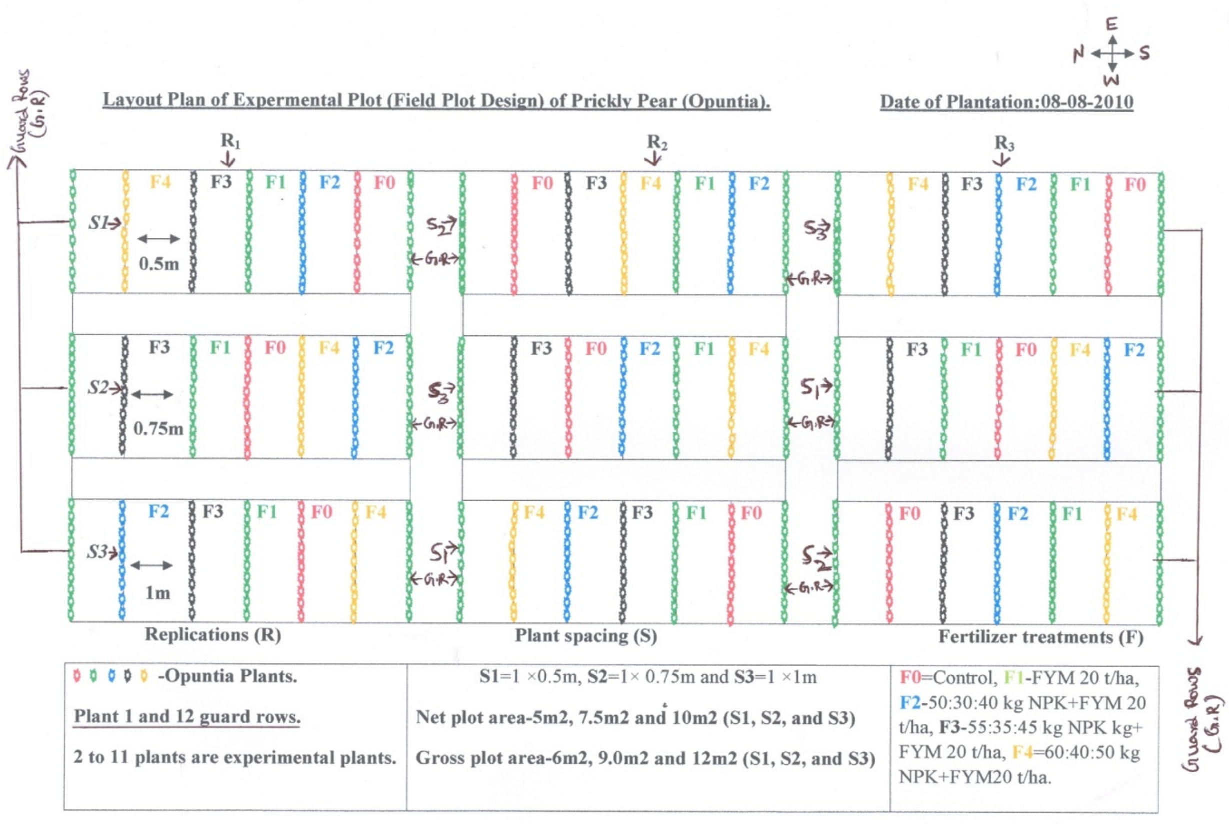

Figure 1: Layout of plantation of different space and fertilization treatment of OFI in agricultural field.

The titrable acidity of the fruit with regard to interaction effects between spacing and fertilizer doses, the treatment S3F4 recorded significantly high acidity of 0.19%, and was significantly superior over the rest of the treatments except S2F4 (0.17%). An increase of ascorbic acid content was observed in each level of spacing with increase in levels of fertilizer doses. On interacting together, there was a continuous increase in ascorbic acid was noticed.

The highest ascorbic acid content of 43 mg/100 g of fruit pulp was recorded in wider spacing S3 (1.0 m2) interacting with higher fertilizer dose F4 followed by S3F3 (38 mg), S3F2 (34 mg), whereas the medium spacing S2 interacting with F4 (42 mg), F3 (32 mg) F2 (32 mg) recorded comparatively low ascorbic acid, but was mediocre in between the interaction effects of S3F4 to F2 and S1F4 to F2. Low ascorbic acid content was noticed in closer spacing S1 (0.5 m2) interacting with F4 (29 mg), F3 (33 mg), F2 (29 mg). Correlation studies revealed that all the six characters viz, cladode yield, harvest index, Stem area index, total soluble solids (TSS), titrable acidity (TA) and ascorbic acid (Vit-C) exhibited non significant, positive correlation with fruit yield (r=0.0529, 0.0033,0.0548, 0.0163, 0.0114 and 0.0545 respectively).

DISCUSSION

Fruit yield is a complex character. To formulate the selection criteria, association analysis is very much useful. Correlation coefficient (r) reveals the extent and nature of interrelationships existing between yield and yield determining characters and among themselves. The knowledge of relationship of various yield contributing characters is of therefore great importance in any crop improvement programme for effective selection. Hence correlation coefficient (r) were worked out in *Opuntia ficus indica(L) Miller* as per Snedecor (1961). Correlation studies revealed that all the six characters viz, cladode yield, harvest index, Stem area index, total soluble solids (TSS), titrable acidity (TA) and ascorbic acid (Vit-C) exhibited non significant, positive correlation with fruit yield (r=0.0529,0.0033,0.0548,0.0163,0.0114 and 0.0545 respectively) in prickly pear (Table 3). Similarly the non significant positive correlations were also established between Harvest index, Stem area index, TSS, titrable acidity and ascorbic acid with cladode yield (r=0.0003, 0.0506, 0.0111, 0.0623 and 0.0265 respectively). The association of the attributes stem area index, TSS, titrable acidity and ascorbic acid with harvest index was also observed to be positive, but non significant (r=0.0006, 0.0004, 0.0045 and 0.0025 respectively). The associations among the other characters viz, Stem area index with TSS, tirtable acidity and Vit-C, TSS with titrable acidity and Vit-C and titrable acidity with Vit-C were also similarly found to be non significant, but positive (r=0.0061, 0.0370, 0.0161, 0.0011, 0.1181 and 0.0104 respectively). The characters titrable acidity (0.1141) followed by stem area index (0.0548), ascorbic acid (0.0545) and cladode yield (0.0529) showed high positive correlations (r) with fruit yield. Similarly high positive associations were also observed between the characters titrable acidity (0.0623) and stem area index (0.0506) with cladode yield; titrable acidity (0.0370) with stem area index and ascorbic acid (0.1181). Barbera et al; (1997, 1995) reported that the fruit size and shape representing the fruit yield was however affected by seed number and weight indicating that the parameters other than seed number and weight such as plant spread, stem area index, cladode yield and ascorbic acid could appear to be the fruit yield determining traits. As such the results of the present study are in agreement with the findings of Barbera et al; (1997, 1995).

The above studies on character association suggest that the characters cladode yield, stem area index, trtrable acidity and ascorbic acid which exhibited high positive association with fruit yield should be considered for selection of Prickly pear clones to improve cladode yield, fruit production, and fruit quality in prickly pear *Opuntia ficus indica (L) Miller*.

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