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Evaluation of tomato (*Solanum lycopersicum* L.) hybrids for growth and yield attributes under coastal conditions of Andhra Pradesh

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Abstract
An investigation was undertaken with fifty mustard genotypes to study the correlation and path coefficient analysis of twelve yield contributing characters. Correlation analysis revealed that seed yield per plant is positively and significantly correlated with harvest index followed by number of secondary branches per plant and number of siliquae per plant at genotypic level. Path coefficient analysis revealed that days to maturity, number of secondary branches per plant, number of siliquae per plant, siliqua length, 1000 seed weight, harvest index and oil content had direct positive effect on seed yield per plant. Whereas, days to 50% flowering, plant height, number of primary branches per plant and number of seed per siliqua had direct negative effects on seed yield per plant both at genotypic and phenotypic levels. Based on the results it has been concluded that harvest index, number of secondary branches per plant and number of siliquae per plant exerted high correlation and direct influence on seed yield per plant. These traits may be considered for selection and to improve the yield of mustard genotypes.

Keywords: Tomato, plant height, leaf area, pericarp thickness, fruit girth, yield

Introduction
Tomato (*Solanum lycopersicum* L.) is a self-pollinated diploid species with twelve pairs of chromosomes (2n=24) and is one of the most important solanaceous vegetable crops grown widely all over the world which includes more than 3000 species. The species of genus "*Lycopersicon*" includes the cultivated tomato, *Solanum lycopersicum*, the only domesticated species, as well as a dozen other wild relatives. The genetic diversity in wild tomatoes, especially the self-incompatible species such as *Solanum chilense* and *Solanum peruvianum* are extensive and originated in the narrow West coast area of South America extending from Ecuador to Chile between the Andes and Nile sea (Jenkins, 1948). It is a very versatile vegetable for culinary purpose. Ripe tomato fruit is consumed fresh as salad, and consumed after cooking by utilizing in the preparation of a range of processed products such as puree, paste, powder, ketchup, sauce, soup and canned whole fruits. Unripe green fruits are used for preparation of pickles and chutney. Tomato ranks third in priority after potato and onion in India but, ranks second after potato in the world. India ranks second in the world next to China in both area and production. In India, tomato is grown in an area of 0.81 million hectares with an annual production of 20.51 million tonnes at a productivity of 21.13 t/ha (NHB, 2018-19).
Tomato has tremendous potential of heterosis for earliness, total yield, resistance attributes and uniformity. Hybrid tomato varieties will continue to predominate high input agricultural systems and may expand under some lower input systems where benefits can be demonstrated. If a hybrid is to be accepted commercially, it must be superior to the cultivars presently grown. This superiority may be expressed in terms of total yield, early yield, nutritional quality, post harvest life, insect pest and disease resistance, adaptability, external appearance, etc. Increased vigor in total yield in tomato to the extent of 300 percent over the commercial variety has been reported. In India, the extent of the cross over the better parent is reported to be up to 263 percent (Dhaliwal, 1986) [7].
Continuous inflow of exotic hybrid varieties and risk of getting appropriate variety at desired time created dilemma among the farmers while selecting suitable tomato hybrids. Uncertainty in timely availability of hybrid seeds can be reduced by cultivation of suitable hybrid cultivar developed in the country (Shrestha and Sah, 2014) [38]. Development of hybrid tomato varieties having desirable characters has proven to be an effective strategy to increase tomato production (Islam *et al*., 2012) [13].

The agro-climatic conditions of coastal Andhra Pradesh are known for its variability, uncertainty and extremity. This region is "hot spot" of almost all the biotic and abiotic stresses, like early or late onset of monsoon, flush rains, erratic and unevenly distributed rainfall, leaf blight, bacterial wilt, fruit rot, fruit borer etc. Hybrids have been found to be more suitable for ensured yield under such extreme agro-ecological situation.

Materials and Methods

The present investigation entitled "Evaluation of tomato (*Solanum lycopersicum* L.) hybrids for growth, yield and quality attributes under coastal conditions of Andhra Pradesh" was carried out during *rabi* 2019 – 2020 to study the performance of six hybrids *viz.*, Arka Abhed, Arka Meghali, Arka Rakshak, Arka Samrat, Arka Vikas, Pusa Hybrid – 4 against two local checks namely, Abhilash (check – 1), Rupa (check-2) at College of Horticulture, Venkataramannagudem, West Godavari Dist. Andhra Pradesh. The experiment was laid out in a randomized block design with six hybrids compared with two local checks and replicated thrice.

Results and Discussion

The results from the present field experiment during *rabi* season of the year 2019 and 2020 on plant height, primary branches, leaf area, number of leaves, days to first flowering and 50% flowering, number of flower clusters per plant and number of flowers per cluster, days to first harvest, pericarp thickness, fruit length, fruit girth, average fruit weight, yield per plant, yield per plot and yield per hectare.

Plant height (cm)

At 30 DAT, plant height (cm) ranged from 39.29 (Arka Meghali) to 42.83 (Arka Rakshak) with a mean value of 41.44. None of the hybrids recorded significantly higher value than the best check Abhilash (42.76). Four hybrids *viz*. Arka Rakshak (42.83), Arka Abhed (42.36), Arka Samrat (42.23) and Pusa Hybrid – 4 (41.89) were on par with check Abhilash. At 60 DAT, plant height (cm) ranged from 77.19 (Arka Vikas) to 94.70 (Arka Samrat) with a mean value of 85.86. Two hybrids *viz*. Arka Samrat (94.70) and Arka Abhed (93.13) recorded significantly higher value than the best check Abhilash (85.06), while the other hybrids Arka Rakshak (88.03), Pusa Hybrid – 4 (87.20) and Arka Meghali (81.40) were on par with it. At 90 DAT, plant height (cm) ranged from 92.26 (Arka Vikas) to 114.51 (Arka Samrat) with a mean value of 100.33. All the hybrids were on par with best check Abhilash (107.82) for this trait.

Plant height is usually a good index of plant vigour, which may contribute towards greater productivity. It might be due to nature of plant growth (i.e. indeterminate and semideterminate) and genotypic variation. Indeterminate types of plants are taller as compared to semideterminate and determinate. Variation in height is attributed due to inherent genetic difference of the hybrids. It confirms the findings of Hazarika and Phookan (2005) [11], Cheema *et al*. (2013) [4], Singh *et al.* (2014) [40]. Similar observation was also made by Dhayani *et al.*, (2017) [8], Jatav *et al.* (2017) [14], Kumar *et al.* (2018) [16], Parmar *et al.* (2018) [26] in different tomato cultivars.

Number of primary branches per plant

At 30 DAT, the number of primary branches per plant were ranged from 4.87 (Arka Meghali) to 5.33 (Arka Rakshak) with mean value of 5.09. None of the hybrids recorded significantly higher value than the best check Abhilash (5.20). Five hybrids *viz.* Arka Rakshak (5.33), Arka Samrat (5.27), Arka Abhed (5.13), Arka Vikas (5.07) and Pusa Hybrid – 4 (5.00) were on par with best check Abhilash. At 60 DAT, number of primary branches per plant ranged from 7.85 (Arka Meghali) to 10.91(Arka Rakshak) with mean value of 9.01. None of the hybrids recorded significantly higher value than the best check Abhilash (9.96). The hybrids *viz.* Arka Rakshak (10.91), Arka Samrat (10.18) and Arka Abhed (9.59) were on par with best check Abhilash. At 90 DAT, number of primary branches per plant ranged from 9.32 (Arka Meghali) to 12.85 (Arka Rakshak) with a mean value of 11.05. None of the hybrids recorded significantly higher value than the best check Abhilash (12.15). Two hybrids, Arka Rakshak (12.85) and Arka Abhed (11.82) were on par with best check Abhilash (12.15). Number of branches decides the production of leaves which in turn decides the efficiency of photosynthesis and number of flowers per plant which may contribute towards better yield. The results were in approval with the work of Kumar *et al*. (2006). Similar findings were also recorded by Shankar *et al.* (2013) [33], Yadav *et al.* (2013) [44], Dhayani *et al.* (2017) [8] and Kumar *et al.* (2017) [20] in different tomato cultivars.

Leaf area (cm^2)

At all growth stages there was significant difference in leaf area among the tomato hybrids. At 30 DAT, leaf area (cm^2) ranged from 13.67 (Arka Vikas) to 20.33 (Pusa Hybrid – 4) with mean value of 16.54. The tomato hybrid Pusa Hybrid – 4 recorded significantly highest leaf area (20.33) than the best check Abhilash (16.67), while the other hybrids were on par with best check Abhilash except Arka Vikas (13.67). At 60 DAT, leaf area (cm^2) ranged from 25.45 (Arka Vikas) to 36.33 (Pusa Hybrid – 4) with a mean value of 29.44. Pusa Hybrid – 4 recorded significantly higher value than the best check Abhilash (28.33) for leaf area, whereas the other hybrids Arka Rakshak (33.74), Arka Meghali (31.67), Arka Samrat (31.00), Arka Abhed (28.00) and Arka Vikas (25.45) were on par with best check Abhilash. At 90 DAT, leaf area (cm^2) ranged from 41.37 (Arka Vikas) to 54.00 (Pusa Hybrid – 4) with a mean value of 46.08. All the other hybrids were on par the best check Abhilash (48.67) except Arka Vikas (41.37).

Leaf area represents photosynthetic plant surface area. More leaf area represents the chances of more carbohydrate synthesis for the transformation in to the fruits. Therefore, leaf area could also be a yield indicator of the hybrids. Variability in leaf area of tomato hybrids was reported by Ahmad and Fehmida (2007) [1], Ali *et al*. (2012) [3] and Dhayani *et al.* (2017) [8] in different tomato cultivars.

Days to first flowering

The number of days taken to first flowering in tomato hybrids ranged from 28.00 (Pusa Hybrid – 4) to 31.67 (Arka Vikas) with mean value of 29.43. All the hybrids were on par with best check Rupa (29.00) for this trait. Earliness could be due to higher capacity of plants to make the assimilates available to the apex during the sensitive phase before flower initiation (Dielmen and Heuvelink, 1992). Similar findings for days to flowering on different hybrids of tomato was reported by Singh *et al.* (2014) [41], Lekshmi and Celine (2015) [21] and

Raja Naik *et al.* (2018) [24] in different tomato cultivars.

Days to 50% flowering

The number of days taken to 50% flowering ranged from 32.33 days (Arka Meghali and Pusa Hybrid - 4) to 37.33 days (Arka Vikas) with a mean value of 34.24. Arka Vikas (37.33) recorded significantly higher number of days to 50% flowering than the best check Abhilash (34.00). All the hybrids were on par with the best check Abhilash in this trait. Similar variation in days to 50% flowering was earlier reported by Neeraja *et al.* (2004) [25], Kumar *et al.* (2017) [20], Kumar *et al.* (2017) [20], Sonam and Sharafat (2017) [42] and Rojalin *et al*. (2019) [31] in different tomato cultivars.

Number of flower clusters per plant

Number of flower clusters produced per plant in different tomato hybrids ranged from 4.60 (Arka Meghali and Pusa Hybrid-4) to 6.33 (Arka Abhed) with a mean value of 5.20. Arka Abhed (6.33) and Arka Samrat (5.80) recorded significantly higher number of flower clusters per plant than the best check Abhilash (5.37). The tomato hybrid Arka Rakshak (5.60) was on par with the best check Abhilash (5.37).

Higher number of flower clusters per plant may lead to greater number of fruits per plant under favourable conditions. This is in confirmation with the studies conducted by several research workers *viz.*, Kumar *et al.* (2006) [18], Sekhar *et al*. (2009) [32], and Singh *et al*. (2014) [40] and Rojalin *et al.* (2019) [31] in tomato hybrids.

Number of flowers per cluster

Number of flowers produced per cluster in tomato hybrids ranged from 5.33 (Arka Meghali) to 6.13 (Arka Abhed) with mean value of 5.74. None of the hybrids recorded significantly higher number of flowers per cluster than the best check Abhilash. All the six hybrids were on par with best check Abhilash (5.87) for this trait.

More number of flowers per cluster might lead to more fruit setting in a particular hybrid under congenial agroclimatic conditions. Similar results on variation in number of flowers per clusters have also been reported by Cheema *et al*. (2013) [4] and Hossain *et al.* (2014) [12] in tomato hybrids.

Days to first harvest

Days to first harvest ranged from 86.00 (Arka Meghali) to 100.67 days (Arka Vikas) with mean value of 91.75. Arka Vikas (100.67) recorded significantly higher number of days to first harvest than the best check Abhilash (91.00). Five hybrids *viz.* Pusa Hybrid – 4 (93.67), Arka Rakshak (90.33), Arka Abhed (90.00), Arka Samrat (88.67) and Arka Meghali (86.00) were on par with best check Abhilash.

The early or late maturity is attributed as genotypic character and somewhat influenced by the environmental factors of any particular growing area. Variability in days to first harvest was observed by Alam *et al.* (2010) [2], Sharma and Sharma (2013) [34] and Fayaz *et al.* (2007) [9] in tomato hybrids.

Fruit length (cm)

Fruit length (cm) among different hybrids ranged from 4.33 (Arka Meghali) to 6.57 (Arka Rakshak) with mean value of 5.56. Arka Rakshak (6.57), Arka Abhed (6.07), and Arka Samrat (6.00) recorded significantly higher fruit length than the best check Abhilash (5.63). Pusa Hybrid – 4 (5.91) was on par with best check Abhilash.

Fruit girth (cm)

The fruit girth (cm) among different tomato hybrids ranged from 5.15 (Arka Meghali) to 7.64 (Arka Abhed) with mean value of 5.75. Arka Abhed (7.64) recorded significantly higher fruit girth than the best check Abhilash. (5.71). Arka Rakshak (5.60), Pusa Hybrid – 4 (5.51) and Arka Samrat (5.50) was on par with best check Abhilash. The variation in fruit girth in different tomato hybrids may be due to variation in genetic makeup of cultivars. Rehman *et al*. (2000) [28] and Golani *et al*. (2007) [10], Kumar *et al.* (2017) [20], Rangamanei *et al.* (2017) and Singh *et al.* (2014) [40] also obtained similar observation for fruit girth in different tomato cultivars.

Pericarp thickness (mm)

The tomato hybrids showed significant difference in pericarp thickness (mm). It ranged from 5.81 (Arka Vikas) to 8.16 (Arka Abhed) with mean value of 7.08. Arka Abhed (8.16) recorded significantly higher pericarp thickness than the best check Abhilash (7.24). Four hybrids Arka Rakshak (7.77), Arka Samrat (7.65), Arka Meghali (7.40) and Pusa Hybrid – 4 (6.81) were on par with best check Abhilash. Comparison of growth and yield performance among different cultivars of tomato for pericarp thickness was observed by Wahundeniya *et al*. (2005). Almost similar findings on variability in fruit pericarp thickness of tomato hybrids have also been observed by Cheema *et al*. (2013) [4], Singh *et al*. (2014) [41], Sonam and Sharafat (2017) [42], Kumar *et al.* (2017) [20] and Devokta *et al.* (2018) [6] in different tomato hybrids.

Number of locules per fruit

Number of locules per fruit ranged from 3.47 (Arka Rakshak) to 5.61 (Arka Abhed) with mean value of 4.06. Arka Abhed (5.61) recorded significantly higher number of locules than the best check Abhilash (4.00), where as other hybrids were on par with check Abhilash for this trait. Fruits with more number of locules were found to be having more juice content in them, whereas fruits with lesser number of locules are said to be physically firmer. Similar results on variability in number of fruit locules have been obtained by Cheema *et al.* (2013) [4], Sonam and Sharafat (2017) [42], Kumar *et al.* (2017) [20], Devokta *et al.* (2018) [6] in hybrid tomatoes.

Number of fruits per plant

Number of fruits per plant ranged from 26.24 (Arka Meghali) to 38.62 (Arka Abhed) with mean value of 29.11. Arka Abhed (38.62) and Arka Rakshak (34.88) recorded significantly higher number of fruits per plant than the best check Abhilash (28.54), while the other hybrids were on par with best check Abhilash. Variation in the number of fruit per plant was due to the genetic make-up of the hybrids as all the hybrids tested were given almost similar type of cultural atmospheric and edaphic environments. The results of present study were in accordance with those reported by Pant *et al.* (2002) and Kumar *et al.* (2006) [18], Sekhar *et al.* (2009) [32], Singh *et al.* (2014) [40], Cheema *et al*. (2013) [4], Fayaz *et al.* (2007) [9], and Parmar *et al.* (2018) [26] noted variability in number of fruits per plant from in tomato hybrids.

Average fruit weight (g)

Fruit weight (g) ranged from 77.29 (Arka Meghali) to 127.70 (Arka Abhed) with mean value of 98.98. Arka Abhed

(127.70), Arka Samrat (119.78) and Arka Rakshak (101.64) recorded significantly highest average fruit weight than the best check Abhilash (99.14). Generally, fruit weight is inversely associated with number of fruits per plant although both of these traits are principal yield attributing traits. The fruit weight which is a function of fruit size (fruit length and girth) is a subject of consumers or market choice. Variability in average fruit weight was reported by several research workers *viz.*, Singh *et al.* (2005), Cheema *et al.* (2013) [4], Sonam and Sharafat (2017) [42], Kumar *et al.* (2017) [20], Ranganamei *et al.* (2017), Singh (2017) and Singh *et al.* (2019) in tomato hybrids.

Yield per plant (kg)

Yield per plant (kg) ranged from 1.90 (Arka Meghali and Arka Vikas) to 4.00 (Arka Abhed) with mean value of 2.81. Arka Abhed (4.00), Arka Samrat (3.73) and Arka Rakshak (3.60) significantly recorded highest yield per plant than the best check Abhilash (2.83). Pusa Hybrid – 4 (2.67) was observed on par with best check Abhilash.

Yield per plot (kg)

Yield per plot (kg) ranged from 47.50 (Arka Meghali) to 100.00 (Arka Abhed) with mean value of 70.31. Arka Abhed (100.00), Arka Samrat (93.33kg), and Arka Rakshak (90.00) recorded significantly maximum yield per plot than the best check Abhilash (70.83). Pusa Hybrid – 4 (66.67) was on par with best check Abhilash. Similar findings were reported by Shivakumar (2000) [36], and Sheferaw (2001).

Yield per hectare (t)

Yield per hectare (t) ranged from 52.77 (Arka Meghali) to 111.11 (Arka Abhed) with mean value of 78.11. Arka Abhed (111.11), Arka Samrat (103.69) and Arka Rakshak (99.99) recorded significantly maximum yield per hectare than the best check Abhilash (78.70). Pusa Hybrid – 4 (74.09) was on par with best check Abhilash.

The fruit yield is supposed to be the ultimate economic trait in tomato as well as in other fruit vegetables. Fruit yield per plant is an accurate assessment of potentiality of a particular hybrid at individual plant level. The data on fruit yield per plant exhibited a wide variability among the hybrids evaluated. Maximum fruit yield per plant of tomato hybrids was due to higher fruit set and higher retention of matured fruits per plant. Similar findings were observed by the Singh *et al*., (2005), Singh *et al.* (2009) [39], Cheema *et al*. (2013) [4], Sonam and Sharafat (2017) [42], Triveni *et al.* (2017) [43], Singh (2017) and Singh *et al.* (2019).

Table 1: Vegetative characteristics at different growth stages in different tomato hybrids

S. No.	Treatments	Plant height (cm)			Number of primary branches			Leaf area (cm^2)		
		30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90DAT	30DAT	60DAT	90DAT
1.	Arka Abhed	42.36	93.13	113.78	5.13	9.59	11.82	15.00	28.00	42.67
2.	Arka Meghali	39.29	81.40	99.16	4.87	7.85	9.32	17.67	31.67	43.00
3.	Arka Rakshak	42.83	88.03	99.42	5.33	10.91	12.85	19.33	33.74	51.00
4.	Arka Samrat	42.23	94.70	114.51	5.27	10.18	11.30	15.67	31.00	48.67
5.	Arka Vikas	39.65	77.19	92.26	5.07	7.89	9.70	13.67	25.45	41.37
6.	Pusa Hybrid -4	41.89	87.20	107.82	5.00	8.48	11.11	20.33	36.33	54.00
7.	Abhilash (check –1)	42.76	85.06	107.82	5.20	9.96	12.15	16.67	28.33	48.67
8.	Rupa (check –2)	40.59	80.16	97.47	4.90	7.26	10.19	14.00	21.00	39.33
	Mean	41.44	85.86	100.33	5.09	9.01	11.05	16.54	29.44	46.08
	SE.m +	0.50	2.35	5.33	0.09	0.40	0.26	0.93	1.79	2.19
	C.D at 5%	1.54	7.12	16.18	0.29	1.22	0.81	2.84	5.44	6.65

Table 2: Flowering characteristics of different tomato hybrids

Treatments	Days to first flowering	Days to 50% flowering	Number of flower clusters per plant	Number of flowers per cluster	Days to first harvest (Days)	Fruit length (cm)	Fruit girth (cm)
Arka Abhed	28.60	33.17	6.33	6.13	90.00	6.07	7.64
Arka Meghali	28.45	32.33	4.60	5.33	86.00	4.33	5.15
Arka Rakshak	30.55	35.60	5.60	5.80	90.33	6.57	5.60
Arka Samrat	29.33	34.83	5.80	5.93	88.67	6.00	5.50
Arka Vikas	31.67	37.33	4.77	5.67	100.67	4.53	5.31
Pusa Hybrid -4	28.00	32.33	4.60	5.73	93.67	5.91	5.51
Abhilash (check –1)	29.89	34.00	5.37	5.87	91.00	5.63	5.71
Rupa (check –2)	29.00	34.33	4.53	5.47	93.67	5.47	5.64
Mean	29.43	34.24	5.20	5.74	91.75	5.56	5.75
SE.m +	0.66	0.67	0.08	0.14	1.96	0.11	0.08
C.D at 5%	2.02	2.03	0.26	0.43	5.95	0.35	0.24

Table 3: Fruit and yield characteristics of different tomato hybrids

Treatments	Pericarp thickness (mm)	Number of locules per fruit	Number of fruits per plant	Average fruit weight (g)	Yield per plant (kg)	Yield per plot (kg)	Yield per hectare (t)
Arka Abhed	8.16	5.61	38.62	127.70	4.00	100.00	111.11
Arka Meghali	7.40	3.87	26.24	77.29	1.90	47.50	52.77
Arka Rakshak	7.77	3.47	34.88	101.64	3.60	90.00	99.99
Arka Samrat	7.65	4.00	29.27	119.78	3.73	93.33	103.69
Arka Vikas	5.81	4.17	26.59	84.40	1.90	47.50	52.77
Pusa Hybrid -4	6.81	3.77	27.63	91.78	2.67	66.67	74.09

Abhilash (check –1)	7.24	4.00	28.54	99.14	2.83	70.83	78.70
Rupa (check –2)	5.87	3.67	21.19	90.13	1.87	46.67	51.84
Mean	7.08	4.06	29.11	98.98	2.81	70.31	78.11
S.Em +	0.22	0.14	1.95	1.98	0.06	1.62	1.80
CD at 5%	0.67	0.44	5.93	6.01	0.19	4.91	5.46

Conclusion

From the present study it can be concluded that the tomato hybrids Arka Abhed, Arka Rakshak can be cultivated under coastal conditions of Andhra Pradesh. The results obtained from the present study revealed that there is a great scope for cultivation under open conditions. Among the different hybrids when compared with check Abhilash, Arka Abhed and Arka Rakshak proved the best in growth and yield parameters.

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