The Pharma Innovation Journal 2023; SP-12(9): 1422-1425

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(9): 1422-1425

www.thepharmajournal.com
Received: 14-07-2023
Accepted: 20-08-2023

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Assessment of Arka Abhed and Arka Samrat tomato hybrids in rainfed areas of Prakasam district

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Abstract
Over a span of three years, a study was carried out to evaluate the performance of tomato hybrids, specifically Arka Abhed and Arka Samrat, known for their high yield and resistance to multiple diseases. This research was conducted in the Prakasam district of Andhra Pradesh, where the majority of farmers traditionally cultivated low-yielding commercial hybrids that were highly susceptible to pests and diseases. Given this agricultural context, the introduction of high-yielding hybrids with resistance to pests and diseases was deemed essential to increase productivity and reduce cultivation costs. Consequently, experiments were conducted to assess the suitability of Arka Abhed and Arka Samrat tomato hybrids in comparison to the locally cultivated US-448 hybrid. The primary branches per plant were found to be 12.33, 10.6, and 9.3, while the number of fruits per plant yielded 102.0, 87.33, and 77.33, and the per-plant yield was 7.3 kg, 6.53 kg, and 5.63 kg, respectively, for Arka Abhed, Arka Samrat, and US-448 hybrids. Furthermore, the average yield was recorded at 51.57 t/ha, 47.03 t/ha, and 42 t/ha, respectively. The new hybrid varieties demonstrated positive results in terms of the Benefit-to-Cost (B:C) ratio, with values of 1:2.60, 2.38, and 2.21 for Arka Abhed, Arka Samrat, and US-448 hybrids, respectively.

Keywords: Arka Abhed, Arka Samrat, high yield, hybrids, tomato

Introduction
Tomato, scientifically known as *Solanum Lycopersicon* L., has attained the esteemed status of being the world's most popular vegetable crop due to its remarkable adaptability to a wide range of agro-climatic conditions. In the region of Andhra Pradesh, tomato cultivation covers an extensive area of 35,000 hectares, resulting in an annual production of approximately one million tonnes and an impressive yield of 30.51 tonnes per hectare. Tomatoes are highly regarded as a protective food crop due to their rich content of essential minerals, vitamins, and organic acids. They serve as a vital source of lycopene, ascorbic acid, and carotene, all prized for their contributions to color, flavor, and antioxidant properties. The rising consumption of tomatoes has elevated its status to that of a high-value crop, providing a significant income source for farmers. It holds great importance from both a production and industrial perspective, necessitating the need to enhance productivity per unit area in order to meet the growing demand within limited arable land. Typically, the utilization of diverse parent plants is expected to result in high hybrid vigor. This approach often allows for the combination of desired genetic traits in a more expedited manner, without the need for protracted waiting periods. Consequently, hybrids tend to exhibit superior fitness and breeding value compared to their individual parent plants. The overarching goals universally sought after include higher yields and improved fruit quality.

In the Prakasa district, horticultural crop cultivation spans an area of 42,208 hectares, with tomato cultivation occupying approximately 980 hectares during the 2022-23 season. Notably, the predominant tomato cultivation in this region is dominated by private hybrids. These private hybrid seeds come at a considerable cost, but due to their widespread availability, farmers are compelled to obtain them for cultivation, even though they often result in lower productivity. Tomato crops in this region are particularly vulnerable to several devastating diseases, including early blight, bacterial wilt (BW), tomato leaf curl virus (ToLCV), and late blight, which collectively contribute to yield losses of up to 30 percent in Andhra Pradesh. These pathogens find conducive conditions for survival either in the soil or in collateral and alternate host plants. The prevalence of these diseases is exacerbated by the farming practices employed by the growers and the persistence of a prolonged favorable environment. Several strategies have been developed to manage these diseases, but challenges persist.

These include the absence of improved pest- and disease-resistant tomato hybrids, the use of low-quality seeds, suboptimal soil fertility, and issues related to disease and insect pests. To address these challenges, a multitude of high-yielding tomato hybrids has been introduced for open field cultivation (Kaddi *et al*., 2014) [7]. In light of this context, there is an urgent need to introduce well-suited, high-yielding, and disease-resistant tomato hybrids in the Prakasam district. Therefore, an investigation was conducted to evaluate the performance of these high-yielding tomato hybrids in Andhra Pradesh's Prakasam district.

Materials and Methods

The seeds of tomato hybrids, Arka Abhed and Arka Samrat, were sown in nursery pots during the first week of September at KVK, Darsi's vegetable nursery unit. Subsequently, the seedlings were transplanted during the second week of October in the years 2020-21, 2021-22, and 2022-23, right into the fields of local farmers. For this on-farm trial, Arka Abhed, Arka Samrat, and the local check variety (US-448) were employed. The seedlings used in the transplantation were between 30 to 35 days old and were spaced at 75 x 45 cm intervals. During the land preparation process, 20-25 metric tonnes per hectare (t/ha) of Farm Yard Manure (FYM) were incorporated into the soil. Furthermore, a combination of NPK fertilizers, with a ratio of 180:100:100 kg/ha, was applied. Half of the nitrogen dose and the full doses of phosphorous and potash were administered during the transplanting phase. The remaining half of the nitrogen was applied in two equal portions, with the first half given 30 days after transplanting and the second half provided 60 days after transplanting, encircling the plant at a 15 cm distance. To ensure high yields, two applications of micronutrient mixtures were carried out at 30 and 60 days after transplanting. Additionally, to combat sucking pests, both Yellow and Blue sticky traps, totaling 20 traps per hectare, were strategically positioned throughout the field. Additionally, the field underwent four rounds of regular weeding to maintain optimal crop conditions.

No plant protection measures were implemented in both the check and trial plots to accurately observe the growth and yield parameters of the tomato hybrids. Tomato F1 hybrid Arka Abhed (H-397) is renowned for its resistance to multiple diseases, including tomato leaf curl disease (ToLCV), bacterial wilt (BW), early blight, and late blight. Arka Abhed tomato plants exhibit a semi-determinate growth habit and possess dark green foliage. The fruits of Arka Abhed are firm, oblate round, and of medium-large size, typically weighing between 90-100 grams. Key characteristics of Arka Abhed include its resistance to late blight, early blight, leaf curl virus, and bacterial wilt, a crop duration of 140-145 days, and a remarkable yield potential of 70-75 tonnes per hectare. This hybrid is suitable for cultivation during the Kharif, Rabi, and summer seasons. Similarly, Arka Samrat is characterized as a triple disease-resistant hybrid, exhibiting resistance to early blight, bacterial wilt, and leaf curl virus diseases. It boasts a notable yield potential of 80-85 tonnes per hectare and requires approximately 140-150 days to complete its crop cycle. Arka Samrat, a high-yielding F1 hybrid, is the result of a crossbreeding between IIHR-2835 and IIHR-2832. It stands out as the first F1 Hybrid to offer triple resistance against tomato leaf curl disease (ToLCV), bacterial wilt (BW), and early blight. The fruits of Arka Samrat are characterized by their oblate to high round shape, large size (ranging from 90-110 grams), deep red coloration, and firm texture. On the other hand, US-448 is a private hybrid variety with plants that exhibit a growth pattern ranging from tall determinate to semi-determinate. These plants feature robust foliage cover and vigor. The time to the first harvest for US-448 is typically 62-67 days. The fruits produced by this hybrid are flat and round, possessing green coloration with a very firm structure and a distinctly acidic taste. Their color matures to a deep red, and the average fruit weight falls within the range of 100-120 grams. Additionally, US-448 exhibits intermediate resistance to tomato leaf curl virus.

The seeds for the tomato hybrids Arka Abhed and Arka Samrat were obtained from the Indian Institute of Horticulture Research (IIHR) in Bengaluru. These two hybrids, Arka Abhed and Arka Samrat, were developed and released by IIHR, Bangalore. Seedlings were raised at the KVK nursery and subsequently distributed to local farmers. A field experiment was conducted across various locations in Darsimandal within the Prakasam district during the Rabi season for three consecutive years: 2020-21, 2021-22, and 2022-23. The experiment utilized hybrids Arka Abhed, Arka Samrat, and the US-448 Hybrid as a reference or check hybrid. The experimental design followed a randomized block layout with five replications. Various traits, including plant height, days to first flowering, days required for 50% flowering, days to the initial harvest, number of fruits per plant, average fruit weight (in grams), fruit yield per individual plant, yield per hectare, net returns per hectare, and the benefit-cost ratio, were meticulously recorded and subsequently subjected to statistical analysis using the methodology outlined by Panse and Sukhatme (1985) [14].

Results and Discussions

The tomato hybrid Arka Abhed exhibited the highest values for various growth, yield, and cost-economic parameters compared to the other hybrids. It achieved a remarkable plant height of 188 cm, followed by Arka Samrat at 166.67 cm, while US-448 had the shortest plant height at 137.67 cm. In terms of the number of primary branches per plant, Arka Abhed displayed the highest count at 12.33, followed by Arka Samrat with 10.67, and US-448 had the fewest primary branches with 9.23. Regarding the duration until the first flowering after planting, Arka Abhed demonstrated the quickest flowering at 29.33 days, followed closely by Arka Samrat at 30.67 days. In contrast, US-448, following traditional farming practices, exhibited a longer duration for flowering at 32.33 days. For the time taken to reach 50% flowering after planting, both Arka Abhed and Arka Samrat showed similar values of 40.33 days. Conversely, US-448, under traditional farming practices, took longer to reach this stage, with a duration of 42.67 days. These differences may be attributed to the genetic makeup of the respective hybrids.

The three-year average results revealed that the US-448 tomato hybrid took the maximum number of days (80.67) from transplanting to the first harvest, closely followed by the Arka Samrat hybrid, which took 77.33 days. In contrast, Arka Abhed had a shorter duration, with only 74 days required. These findings align with previous research by Abrar *et al*. (2011) [1] and Falak *et al*. (2011) [3], which reported that the time taken from transplanting to the first harvest for various tomato cultivars typically falls within the range of 69 to 84 days. Arka Abhed stood out by recording the highest number of fruits per plant at 102.0, followed by Arka Samrat with 87.33, and the farmers' practice (US-448) with 77.33. This

observation is consistent with earlier research conducted by Islam *et al*. (2012) [5], Marbhal *et al*. (2016) [10], Kyess *et al*. (2017) [8], and Vijeth *et al*. (2018) [16], all of whom reported that most hybrids outperformed control varieties in terms of the total number of fruits produced per plant in their studies. It's important to note that fruit weight, influenced by factors like fruit length and diameter, may be a consideration for consumers or specific market preferences. However, the number of fruits per plant is independent of the intended end use. Therefore, priority should be given to hybrids with a higher number of fruits per plant rather than those producing larger, bulkier fruits, as emphasized by Mohan Singh *et al*. (2019) [12].

Fruit weight is indeed a critical factor directly contributing to the yield per plant. Arka Samrat exhibited an average fruit weight of 107.67 grams, while Arka Samrat was nearly on par with US-448, with a mean fruit weight of 107.33 grams. In contrast, Arka Abhed had the lowest fruit weight, averaging at 98.67 grams. It's important to note that variations in fruit diameter among these hybrids are influenced by cell size and intercellular space within the flesh, as discussed by Singh *et al*. (2019) [12]. Table 1 clearly demonstrates that among the three tomato hybrids, Arka Abhed achieved the highest fruit yield per plant at 7.33 kilograms, surpassing Arka Samrat (6.53 kg) and US-448 (5.63 kg). These variations in yield per plant may be attributed to the genetic makeup of the plants, including factors such as the number of flowers and the percentage of fruit set, which are often higher in vigorous and healthy plants. Such genetic distinctions in marketable fruit yield and other plant characteristics across different tomato hybrids have also been reported by Jindal *et al*. (2018) [6]. In terms of yield per hectare, Arka Abhed once again outperformed the other hybrids, recording the highest mean yield at 51.57 tonnes per hectare, followed by Arka Samrat at 47.03 tonnes per hectare. The lowest yield was observed in the case of farmers' practice, registering at 42.00 tonnes per hectare.

Economics

Both the Arka Abhed and Arka Samrat hybrids outperformed the US-448 hybrid in various aspects, including the number of pickings, average fruit weight, yield, and price per kilogram. For Arka Abhed, the cost of cultivation per hectare amounted to Rs. 198,000, resulting in an average yield of 51.57 tonnes per hectare. Farmers sold tomatoes at an average price of Rs. 10 per kilogram, generating gross returns of Rs. 515,666.67 per hectare and high net returns of Rs. 317,666 per hectare, with a benefit-cost (B:C) ratio of 1:2.60. Similarly, Arka Samrat incurred a cost of cultivation of Rs. 198,000 per hectare and achieved an average yield of 47.03 tonnes per hectare. Tomatoes were sold at Rs. 10 per kilogram, yielding gross returns of Rs. 470,333.3 per hectare and net returns of Rs. 272,333, with a B:C ratio of 1:2.37. In contrast, the cost of cultivation for US-448 was Rs. 190,000 per hectare, resulting in an average yield of 42.00 tonnes per hectare. Due to considerations related to fruit quality and shelf life, the unit price of US-448 hybrid was reduced compared to Arka Abhed. Arka Abhed exhibited a substantial 18.55% increase in yield, while Arka Samrat showed a 10.69% increase in yield compared to the US-448 hybrid, enjoying greater market preference over the farmers' practice of US-448 hybrid. The data revealed that the interaction effect of the year and hybrid was not significant, indicating that the three hybrids performed consistently over the two years. Moreover, Arka Abhed exhibited superior performance with a higher fruit yield of 51.57 tonnes per hectare compared to Arka Samrat (47.03 tonnes per hectare) and US-448 (42.00 tonnes per hectare). These findings align with similar results reported by Sunitha *et al*. (2020) [15].

Table 1: Performance for growth and yield of different hybrids of tomato hybrids

Particulars	Arka Abhed							Arka Samrat							US-448						
	20-21	21-22	22-23	Mean	SD	t value	p value	20-21	21-22	22-23	Mean	SD	t value	p value	20-21	21-22	22-23	Mean	SD	t value	p value
Plant height (cm)	198	177	189	188.00	198	177	189	181	163	166.67	128	188.00	181	163	148	137	137.67	181	166.67	128	148
Primary branches per plant	14	11	12	12.33	14	11	12	13	9	10.67	8	12.33	13	9	11	8.7	9.23	13	10.67	8	11
days to first flowering	29	31	28	29.33	29	31	28	28	31	30.67	32	29.33	28	31	34	31	32.33	28	30.67	32	34
Days taken for 50% flowering	42	39	40	40.33	42	39	40	42	43	40.33	44	40.33	42	43	41	43	42.67	42	40.33	44	41
Days to first harvest	75	78	69	74.00	75	78	69	75	76	77.33	78	74.00	75	76	84	80	80.67	75	77.33	78	84
Number of fruits per plant	110	94	102	102.00	110	94	102	97	76	87.33	71	102.00	97	76	88	73	77.33	97	87.33	71	88
Average fruit weight (g)	95	105	96	98.67	95	105	96	98	115	107.67	120	98.67	98	115	100	102	107.33	98	107.67	120	100
Fruit yield per plant	7.3	6.5	8.2	7.33	7.3	6.5	8.2	6.2	7.6	6.53	6.2	7.33	6.2	7.6	4.8	5.9	5.63	6.2	6.53	6.2	4.8
Yield per hectare	50.9	52.3	51.5	51.57	50.9	52.3	51.5	45.3	46.9	47.03	38.9	51.57	45.3	46.9	45.3	41.8	42.00	45.3	47.03	38.9	45.3

Table 2: Cost of cultivation and economics of different tomato hybrids.

Particulars	Arka Abhed				Arka Samrat				US-448			
	2020-21	2021-22	2022-23	Mean	2020-21	2021-22	2022-23	Mean	2020-21	2021-22	2022-23	Mean
Yield per hectare	50.90	52.30	51.50	51.57	48.90	45.30	46.90	47.03	38.90	45.30	41.80	42.00
Cost of cultivation	195000	201000	198000	198000	195000	201000	198000	198000	200000	180000	210000	190000
Gross Returns	509000	523000	515000	515666	489000	453000	469000	470333	389000	453000	418000	420000
Net returns	314000	322000	317000	317666	294000	252000	271000	272333	189000	273000	208000	230000
B:C Ratio	2.61	2.60	2.60	2.60	2.51	2.25	2.37	2.38	1.95	2.52	1.99	2.21

Conclusion

In conclusion, the cultivation of Arka Abhed and Arka Samrat hybrids in Prakasam district, Andhra Pradesh, has been proven to be highly beneficial based on the results obtained. Among the three hybrids under study, Arka Abhed exhibited superiority in terms of yield and various yield-related parameters, including the number of fruits, fruit weight, total yield per plant, and yield per hectare, followed closely by Arka Samrat. As a result, farmers in the region have realized the potential for maximizing marketable crop yield by cultivating Arka Abhed and Arka Samrat in Prakasam district.

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