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Performance Evaluation of Farmers' Onion Varieties against Purple Blotch Disease

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Authors' contributions

This work was carried out in collaboration among all authors. Author NP conducted the study at Gandhinagar locations, performed statistical analysis and wrote the first draft of the manuscript. Author HC developed the test protocol, conceptualized the study and supervised in-house and out-sourced studies at Gujarat and Maharashtra respectively. He also critically reviewed and edited the manuscript. Authors VVS and VGM conducted the experimental trials at Agricultural Research Station Repoli, Maharashtra. Authors USK, LKG, ASD and SBG conducted the experiments at Agricultural Research Station Palghar, Maharashtra. Author BM assisted in data collection in Gujarat. Authors SVG and BNP are the innovators of the varieties and provided the seed materials for this study. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To evaluate the performance of farmers' onion varieties against purple blotch disease at different locations and to correlate Percent Disease Index with yield attributing and other important traits.
Study Design: Randomized Block Design, Field demonstration.
Place and Duration of Study: National Innovation Foundation- India Gandhinagar Gujarat, Repoli and Palghar research stations of Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli Maharashtra during October 2017 to April 2019.

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Methodology: Two farmers' onion varieties *Sona-40* and *Sandip* were characterized and tested for their response against purple blotch disease under field condition in comparison with location-specific check varieties. Percent Disease Index of purple blotch was observed, compared and correlated with important traits *viz.* the plant height, leaves per plant, bulb diameter, maturity period, bulb weight, bulb yield and keeping quality. In Maharashtra areas, the study was conducted under Repoli and Palghar conditions during winter (Rabi) 2017, whereas at Gandhinagar Gujarat, it was undertaken in winter (Rabi) 2017 and 2018.
Results: The farmers' onion cultivars *Sandip* and *Sona-40* were found to be tolerant to the purple blotch disease at all the locations. In Maharashtra and Gujarat, the average Percent Disease Index (PDI) in *Sona-40* (12.1%, 12.2%) and *Sandip* (10.75%, 14.64%) was found significantly lower as compared to the checks respectively. The present studies also confirmed that onion bulb's yield, weight and keeping quality were significantly correlated with the purple blotch disease.
Conclusion: This study exhibited that the farmers' onion varieties may perform better against disease infestation such as purple blotch disease. It also confirmed that the response of the onion varieties against purple blotch may vary in different locations. It is shown that the bulb weight, yield and shelf life of bulbs are significantly affected by purple blotch disease.

Keywords: Onion; purple blotch disease; farmers' crop varieties.

1. INTRODUCTION

Onion (*Allium cepa* L.) is an important vegetable crop of Alliaceae family. It has been cultivating as one of the oldest vegetables for its characteristics, pungent flavor and medicinal properties. In India, it is grown across the country in which Maharashtra, Gujarat, and Karnataka are the key onion producing states contributing over 50% of the total production of the country. The total onion production in India during 2017-2018 was 23.26 million tons, of which 37% was the highest production in Maharashtra and Gujarat was in the ninth position in terms of production with 0.54 million tons [1]. In Gujarat, major onion cultivating areas are in Bhavnagar, Rajkot, Jamnagar, Amreli, Junagadh, and Kutch districts with the productivity of 25.48 tons per hectare [2]. The total agricultural area of Gujarat is 9.9 million hectares, while area under organic practice is 74,381 hectares which are 0.75 % of the total agriculture area of Gujarat [3].

In Gujarat and Maharashtra majority of the farmers cultivate high yielding onion varieties released by state agricultural universities or national research institutes such as GWO-1, N-53, Puna Fursungi, Nashik red, etc. by following the contemporary practices of cultivation using chemical fertilizers and pesticides with higher input costs and fluctuating insignificant profits [4,5]. Nowadays awareness and demand for organic produce have been increasing among the new generation, therefore farmers are inclined to adopt organic onion cultivation for quality production and additional income generation. Among different constrains of organic onion cultivation, the unavailability of quality seeds and optimized package of practices are major concerns [6]. Apart from this, farmers faced the problems of pests and diseases management, adverse environmental conditions and poor storage facilities also [7,8]. Purple Blotch disease is one of the dreaded diseases of onion crop. It engulfs every field of onion in the world and causes 30 to 100% crop loss under its favorable condition [9,10]. The onion crop is affected by purple blotch foliar disease in different extents depending upon varieties and climatic conditions mainly temperature and humidity [11]. It is caused by the fungal agent *Alternaria porri* (ellis) cif. and frequently occurs in Gujarat [5] and other onion growing areas of the country [10]. In humid condition spores of the fungus germinate on the leaf surface which creates water-soaked lesions with white center, which further grow and turn brown to purple with the yellowish surroundings. The infestation covers the leaves and crops based on the severity of the disease and causes the tip dieback. Purple blotch symptoms may occur in 4-5 days after the infection and spread through the repeated cycle of spore production and infestation through the lesions. It badly affects the crop performance, bulb quality and enhances the secondary infestation on the crops.

Farmers' plant varieties are conserved or traditionally being cultivated and developed by the farmers in their field; such varieties are relatives of traditional varieties or landraces about which farmers possess common

knowledge. These varieties are rich in diversity and nutritional traits [12]. As farmers' crop varieties are rich in genetic diversity and known for better capability to adapt and perform against insects, pests and diseases. The input cost of the farming may also be reduced by using improved farmers' developed crop varieties as farmers themselves can prepare the seed for next season. In the present study, two potential farmers' varieties of onion were evaluated against purple blotch disease and for their performance under field conditions of Maharashtra and Gujarat during 2017-18 and 2018-19 respectively.

2. MATERIALS AND METHODS

2.1 Farmers' Onion Varieties

Two farmers' varieties of onion were taken from National Innovation Foundation – India (NIF) received in its 9th National Biennial Competition as experimental material in comparison with locally popular check varieties. These varieties namely *Sona-40* (Wadgaon Daula Selection) and *Sandip* were developed by the grassroots innovators Babasaheb N. Pisore and Sandip V. Ghole respectively from Maharashtra through mass selection based on desirable traits such as disease free plants with bigger and uniform sized of inflorescence and bulbs, free from bolting and splitting, strong adherence dry skin of bulb after harvesting, thick rings and excellent storage life.

2.2 Evaluation Study at Maharashtra and Gujarat

Performance evaluation trials of *Sona-40* and *Sandip* varieties of onion were carried out at Agricultural Research Stations, Palghar (19°41'20.0"N 72°45'18.9"E) and Repoli (18°11'11.3"N 73°19'11.4"E) under Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra during 2017-18. Two separate trials were also conducted in winter (Rabi) seasons for two successive years during 2017-18 and 2018-19 at NIF's experimental farm, Amrapur (23°21'38.2"N 72°42'45.2"E), Gandhinagar, Gujarat, India. The study was performed by using Randomized Complete Block Design, where block size was 25 m^2 with spacing of 15 x 10 cm between rows and plants. The variety which was found to be superior in first year trial (2017-18) was also evaluated during 2018-19 in comparison with local commercial cultivated variety through on-farm trial at Grambharti's organic field of 1620 m^2 area which was situated in Gandhinagar at 23°22'36.9"N 72°42'00.3"E.

2.3 Package of Practice

The location wise recommended cultivation practices were adopted to raise the crop in Maharashtra and Gujarat. The organic cultivation practices were also followed during on-farm trial conducted at organic demonstration plot. The nursery bed of 2-meter-long, 1.2-meter-wide and 10 cm above the ground level was prepared and farm yard manures were applied (20 kg) then seeds were sown at the rate of 8 kg/ha during November. Irrigation was applied through manual sprinkle on the bed at the intervals of 5 days. For transplantation of four varieties as treatment in five replications, experimental blocks (12 m^2) were prepared after ploughing in the distance of 75 cm. Vermicompost was applied at the rate of 7.5 tons per hectare after block preparation. 30 days old seedlings of uniform size were transplanted with the spacing of 15 x 10 cm between rows and plants.

2.4 Observation and Statistical Analysis

The test varieties were characterized based on the parameters of foliage and bulb descriptors derived from DUS guideline of onion published by the Protection of Plant Varieties and Farmers' Rights Authority, New Delhi (PPVFRA). The foliage parameters (attitude, waxiness Intensity of green colour, cranking) and bulb traits (like diameter, degree of splitting, shape, colour of dry skin, adherence of dry skin after harvesting, colour of epidermis of fleshy scale, predominant number of axes, cross section of bulb and total soluble solids) were also documented [13,14]. The purple blotch disease incidence was recorded by taking 0 to 5 scale (Table 1) after three and half months of transplantation [15]. Percent Disease Index (PDI) was calculated for categorizing the varieties for their susceptibility or resistance against purple blotch disease [16,17].

$$PDI = \left(\frac{Total\ sum\ of\ numerical\ ratings}{Number\ of\ observations}\right) X\ \frac{100}{Maximum\ disease\ ratings}$$

Table 1. Scale adopted to indicate degree of resistance against purple blotch of onion

Percent Disease Incidence (PDI)	Scale (0-5)	Reaction	Disease Incidence
<5	0	Immune	No disease symptom
5-10	I	resistant	A few spots towards tip covering 10 percent leaf area.
11-20	II	Moderately resistant	Several purplish brown patches covering upto 20 percent of leaf area.
21-40	III	Moderately susceptible	Several patches with paler outer zone covering upto 40 percent leaf area.
41-60	IV	Susceptible	Leaf streaks covering upto 75 percent leaf area or breaking of the leaves from center
>61	V	Highly susceptible	Complete drying of the leaves or breaking of leaves from center

In order to evaluate the performance of the varieties, the observations of yield and yield associated traits such as plant height (cm), number of leaves per plant, number of days to maturity, average bulb weight (gm), number of rings per bulb, ring size (cm), average bulb diameter, keeping quality and bulb yield (tons/hectare) were recorded using standard methods [6,18]. The observations were recorded from 10 randomly selected plants or part of the plant for each character. The yield of marketable bulb was converted to tons per hectare. Pooled analysis was done for the data generated in the studies of two years.

The data were then subjected to analysis of variance and critical difference (CD) values at p=0.05. Three superior varieties out of four has compared for each location and year. Percentage superiority of farmer's variety over check was also calculated for each location and year. Correlation analysis was carried out by 'R corrplot package' of R program to study the relationship of between PDI with other parameters.

3. RESULTS AND DISCUSSION

3.1 Morphological Characterization

The morphological descriptors of two farmers' onion varieties are presented in Table 2. There were no variations found in foliage traits among the two farmers' varieties *viz.*, Foliage attitude (erect), Foliage waxiness (present), Intensity of green colour of foliage (dark) and Foliage cranking was 'Absent' in both *Sandip* and *Sona-40*. Among nine bulb descriptors studied, eight were found with no variations in both the varieties viz. Bulb diameter (Large), Adherence of skin (Strong), Bulb colour of epidermis of fleshy scale (white), Predominant number of axes (Single) and Bulb cross sectional structure (Symmetrical). The degree of splitting into bulblets was 'Absent', colour of dried skin was 'Light red', Total soluble solids (TSS) was 'Medium' in both *Sona-40* and *Sandip* varieties. Bulb shape of *Sona-40* was of Flat globe whereas *Sandip* had Globe shaped bulb. Many of earlier studies reported the variability among local onion varieties [13,19,20 and 21]. Different genetic content leads to such variation in shape of the bulbs, which is also helpful in identification and characterization of the onion germplasms [22].

3.2 Performance Evaluation

The results were found with significant (p=0.05) differences in numerous parameters among the farmers' and check varieties in Maharashtra and Gujarat conditions. Farmers' onion varieties outperformed for yield attributing traits and incidence of purple blotch disease as compared to the checks. Bulb diameter and bulb yield of farmers' varieties were recorded significantly (p=0.05) higher over check at all locations studied.

3.2.1 Percent disease index (PDI) of purple blotch

Incidence of purple blotch disease was reported with significant (p=0.05) difference in all tested onion varieties during field evaluation at all the locations. In Palghar and Repoli, *Sona-40* (11.2%, 13%) and *Sandip* (10.10%, 11.4%) showed significantly lower PDI as compared to the check *Agrifound light red* (14.2%, 17.4%) (Table 4). In individual years and pooled evaluation under Gandhinagar conditions, PDI in *Sona-40* (11.3%, 13.3%, 12.2%) and *Sandip*

(14.7%, 14.6%, 14.64%) was found significantly lower as compared to *Puna Fursungi* (21.1%, 18.95, 20%) (Fig. 1). *Sandip* variety showed 59.5 % lower PDI of purple blotch as compared to local check under organic cultivation at Grambharti's field (Fig. 2).

In the present study farmers' onion varieties (*Sona-40, Sandip*) and check varieties (*Agrifound light red, Puna Fursungi*) were found as 'Moderately Resistant' in Maharashtra and Gujarat conditions whereas local check variety of Gujarat was found as 'Moderately Susceptible' to purple blotch disease (Table 1, Fig. 1). Farmers developed these varieties through mass selection based on desirable traits in healthier plants. Due to specific onion genotypes, they may have tolerance against purple blotch disease. It is also reported that genotypes rich in compounds (viz. vitamin C, pyruvic acid, phenol) hinder the infection and development of the disease symptoms [23]. A study performed by Sarnobat et al. (2020) on status of onion disease in India also confirmed the high incidence of purple blotch in winter (Rabi) and monsoon (Kharif) cultivation [24]. In an earlier study by Jethava et al. (2019), it was reported that the onion variety *GJWO-3* showed lower intensity (13.85 %) of purple blotch disease in Gujarat conditions [5]. Bal et al. (2019) reported *Agrifound light red* as a 'Moderate Susceptible' variety against purple blotch disease in West Bengal however in our study it was found as 'Moderately Resistant' in Maharashtra condition [8].

3.2.2 Plant height and number of leaves

Evaluation studies at Maharashtra and Gujarat areas revealed that the plant height and leaves per plant of both the farmers' varieties were at par with the range of 30.8-43.4 cm and 5.5-8.6 respectively (Table 3). Both the farmers' varieties exhibited significantly higher plant heights and number of leaves as compared to check *Agrifound light red* in both the locations of Maharashtra (Table 3), however they were found at par with check *Puna Fursungi* in Gujarat area during both the years and pooled analysis (Table 5). Plant height and number of leaves of *Sandip* was 13.55% and 34.29% higher as compared with local check under organic cultivation at Grambharti farm, Gandhinagar, Gujarat (Fig. 2). Farmers' varieties were found with more plant

Table 2. Descriptions of farmers' onion varieties [14]

Characteristics and States	*Sona-40* (Wadgaon Daula Selection)	*Sandip* (Patas Selection)
Foliage attitude (Erect, Semi erect)	Erect	Erect
Foliage waxiness (Absent, Present)	Present	Present
Intensity of green colour of foliage (Light, Medium, Dark)	Dark	Dark
Foliage Cranking (Absent, Weak, Strong)	Absent	Absent
Bulb Size (Diameter based) Small (<4.5 cm), Medium (4.5 – 6.0 cm), Large(> 6.0 cm)	Large	Large
Bulb degree of splitting into bulblets [Absent, Medium (<20%), High (>20%)]	Absent	Absent
Bulb Shape (Elliptic, Oval, Globe, Flat globe, Flat)	Flat globe	Globe
Colour of dry skin of Bulb (White, Yellow, Pink, Light red, Dark red, Brown, Purple)	Light red	Light red
Adherence of skin after harvest (Weak, Medium, Strong)	Strong	Strong
Bulb Colour of epidermis of fleshy scale (Whitish, Yellowish, Reddish, Purplish)	Whitish	Whitish
Predominant number of axes in bulb (Single, Multiple)	Single	Single
Bulb cross sectional structure (Asymmetrical, Symmetrical)	Symmetrical	Symmetrical
Total soluble solids (TSS) of bulb [Low (<10%), Medium (10-15%), High (>15%)]	Medium	Medium

height and higher number of leaves in Maharashtra area as compared to the Gujarat. Based on these results, it is confirmed that the plant height and leaves per plant of onion varieties may vary from location to location. The variation in plant height and number of leaves among the varieties could be due to the differences in their genetic traits. Gebretsadik and Dechassa (2018) stated that the difference among the plant height and number of leaves was might be due to soil fertility and variation in the climatic conditions [25].

Table 3. Testing of farmers' varieties of onion at Palghar and Repoli, Maharashtra

Onion	Plant height (cm)		No. of leaves		Maturity (days)		Bulb weight (gm)	
	Palghar	Repoli	Palghar	Repoli	Palghar	Repoli	Palghar	Repoli
Sona-40	43.4	43.8	9.25	9.4	118.6	118.4	73.4	73.2
Sandip	40.6	41.8	10.4	10	121.4	121.2	82.4	82.6
Agrifound-light-red	31.4	31.8	7.2	6.8	124.2	124	64.8	65.2
SEm+	1.37	3.02	0.48	0.52	0.46	0.7	2.17	0.89
CD (P=.05)	4.28	9.31	1.51	1.61	1.43	2.14	6.77	2.74
CV%	8.25	17.83	13.02	13.35	0.84	1.28	6.78	2.76
Sandip (SoC) (%)	29.3	31.45	44.4	47.06	2.3	2.26	27.2	26.69
Sona-40 (SoC) (%)	38.2	37.7	28.5	38.2	4.5	4.5	13.3	12.3

**SoC=Superiority over check, CD= Critical Difference, CV=Coefficient of variance, SEm= Standard error of means*

Table 4. Testing of farmers' varieties of onion at Palghar and Repoli, Maharashtra

Onion	Bulb diameter (cm)		Keeping quality (Days)		Bulb yield (Tons per hectare)		PDI (%) Purple blotch	
	Palghar	Repoli	Palghar	Repoli	Palghar	Repoli	Palghar	Repoli
Sona-40	5.22	5.37	35.4	35.6	33.65	33.57	11.20	13.00
Sandip	4.88	4.45	41	40.2	38.25	37.87	10.10	11.40
Agrifound light red	4.77	4.39	33	33	30.46	30.56	14.20	17.40
SEm+	0.11	0.17	0.3	0.44	0.85	0.54	0.85	0.93
CD (P=.05)	ns	0.51	0.93	1.34	2.66	1.66	2.55	2.87
CV%	5.36	7.78	1.91	2.80	5.73	3.63	10.80	15.07
Sandip (SoC) (%)	2.3	1.37	24.2	21.82	25.6	23.92	28.9	34.48
Sona-40 (SoC) (%)	9.4	22.3	7.3	7.9	10.5	9.8	21.1	25.3

**SoC=superiority over check, CD= critical difference, CV=coefficient of variance, SEm= Standard error of means*

Table 5. Evaluation of farmers' varieties of onion at Gandhinagar, Gujarat, India

Onion	Plant height (cm)			Days to maturity			Number of leaves		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Sona-40	41.44	30.82	36.1	121.2	122.4	121.80	7.6	5.5	6.6
Sandip	40.44	33.68	37.1	124.4	125.6	125.00	7.9	5.6	6.8
Puna Fursungi	39.32	42.3	40.8	119	120.2	119.60	8.6	5.7	7.1
S.Em.+	0.97	2.91	1.9	3.82	5.06	4.4	0.4	0.3	3.0
CD (P=.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV%	5.39	18.41	11.9	7.03	9.18	8.10	19.08	4.98	16.21

**CD= critical difference, CV=coefficient of variance, ns= non-significant, SEm= Standard error of means*

Table 6. Evaluation of farmers' onion varieties at Gandhinagar, Gujarat

Onion varieties	Bulb diameter (cm)			Keeping Quality (Days)		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Sona - 40	4.9	5.12	5.0	33.4	34.2	33.80
Sandip	4.98	5.42	5.2	38.2	37.8	38.00
Puna Fursungi	4.80	5.82	5.6	31	31.4	31.20
S.Em.+	0.56	0.3	0.3	2.01	1.04	1.53
CD (P= 0.05)	ns	ns	ns	ns	ns	ns
CV%	21.35	13.23	13.23	13.43	6.67	10.05

**CD= critical difference, CV=coefficient of variance, ns= non-significant SEm= Standard error of means*

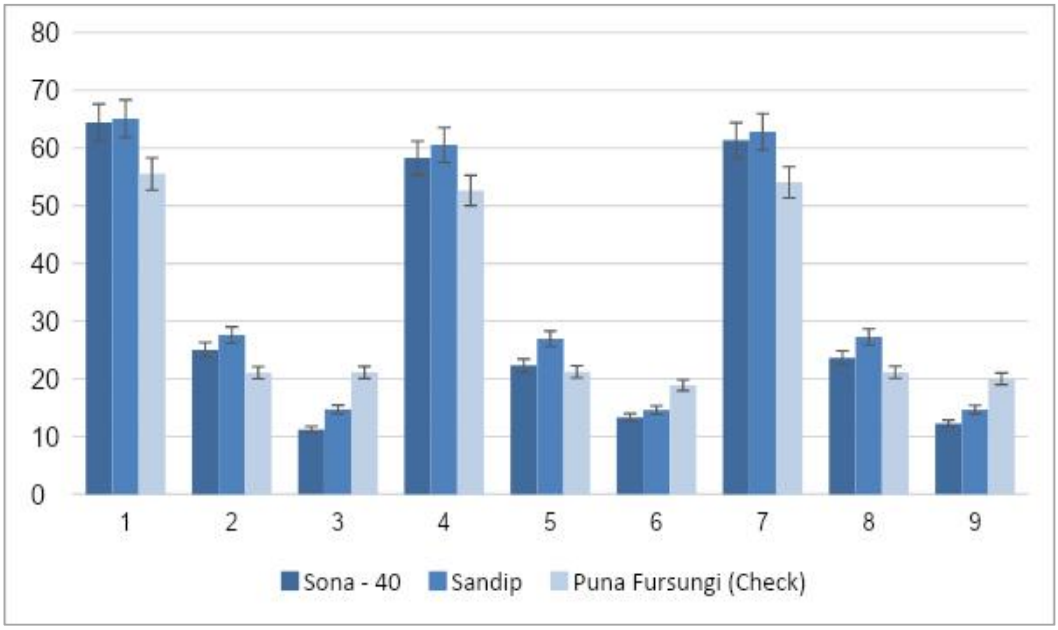


Fig. 1. Response of farmers' onion varieties against purple blotch disease at Gandhinagar, Gujarat

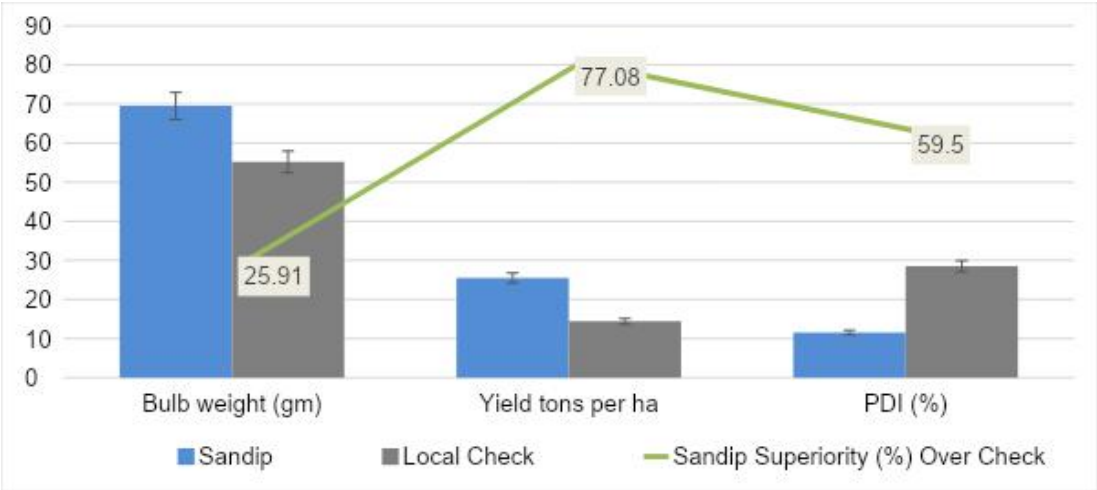


Fig. 2. Performance of *Sandip* and local check in organic cultivation at Gandhinagar Gujarat

3.2.3 Days to the maturity

All tested varieties shown early maturity at all the locations of Maharashtra and Gujarat. In Maharashtra, it was found that both the farmers' varieties namely *Sona-40* and *Sandip* took 118.6 and 121.2 days respectively to mature which was significantly lower as compared to check *Agrifound light red* (Table 3). Individual years and pooled analysis at Gujarat showed that during 2017-18 and 2018-19, the maturity periods of the farmers' varieties were at par with the range of 119.6-125 days, however *Puna Fursungi* and local check took lesser days to mature as compared to farmers' varieties (Table 5, Fig. 2). Earlier studies reported that the days to maturity in onion significantly depends on planting methods and the genotypes [26]. Study of Ganei et al. (2019) also reported significant differences in days to maturity among different onion varieties [20].

3.2.4 Diameter and bulb weight

Diameter and weight of bulbs play important role in market value of onion. Diameters of the onion varieties were found (4.45 cm to 6.56 cm) at par in Maharashtra and Gandhinagar conditions (Table 4, 6). Evaluation study at Palghar and Repoli (Maharashtra) confirmed that the bulb weight of *Sandip* variety (82.4 & 82.6 gm) was significantly higher as compared to *Sona-40* (73.4 & 73.2 gm) and *Agrifound light red* (64.8 & 65.2 gm) (Table 6).

Under Gandhinagar condition, during 2017-18, 2018-19 and pooled analysis, it was observed that the bulb weight of *Sandip* (60.52 gm, 65.10 gm, 62.80 gm) and *Sona-40* (58.26 gm, 60.40 gm, 61.33 gm) was superior as compared to *Puna Fursungi* (56.98 gm, 55.50 gm, 56.24 gm) (Fig. 1). The bulb weight of *Sandip* (69.5 gm) was found 25.9% higher as compared to local check variety under organic cultivation at Grambharti's farm (Fig. 2). Similarly, the reports of Tripathy et al. (2014) and Behera et al. 2017 suggested that the different varieties may have different diameters and weight of bulbs in different locations [27,28].

3.2.5 Bulb yield and keeping quality

Bulb yield and keeping quality of farmers' onion varieties were reported superior as compared to check under Maharashtra and Gujarat conditions. *Sandip* showed significantly higher yield (38.25 & 37.87 tons per hectare) and superior keeping quality (41 & 40.2 days) as compared to the *Sona-40* and check variety at both the locations of Maharashtra (Table 4). Whereas the yield of *Sona-40* (25.01, 22.30 & 23.66 tons per hectare) and *Sandip* (27.63, 26.93 & 27.28 tons per hectare) was significantly higher at Gandhinagar location (Fig. 1) while keeping quality of them were at par with *Puna Fursungi* (check) during both the years and pooled analysis (Table 6). The yield of *Sandip* was recorded 77% higher as compared to local check at Grambharti's organic farm during 2018-19 (Fig. 2). Yield and keeping quality both

Table 7. Correlations with confidence intervals among PDI % and other parameters

Variables	1	2	3	4	5	6	7
1. Plant height							
2. Leaves per plant	-0.12 [-.76, .64]						
3. Bulb diameter	-0.37 [-.85, .45]	0.39 [-.44, .86]					
4. Maturity period	-0.24 [-.81, .56]	-0.22 [-.80, .57]	-0.39 [-.86, .43]				
5. Bulb weight	-0.29 [-.83, .52]	0.72* [.03, .94]	0.16 [-.62, .78]	-0.11 [-.76, .64]			
6. PDI%	0.41 [-.42, .86]	-0.68 [-.94, .04]	-0.44 [-.87, .38]	-0.12 [-.76, .64]	-0.82* [-.97, -.29]		
7. Bulb yield	-0.39 [-.86, .44]	0.70 [-.01, .94]	0.29 [-.52, .82]	0.07 [-.67, .74]	0.86** [.40, .97]	-0.96** [-.99, -.81]	
8. Keeping quality	-0.33 [-.84, .49]	0.45 [-.38, .88]	0.15 [-.62, .77]	0.12 [-.64, .76]	0.76* [.12, .95]	-0.81* [-.96, -.24]	0.82* [.27, .97]

*Note. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation. * indicates p < 0.05. ** indicates p < 0.01 [33]*

are complex traits affected by many variables. Superior yield of the farmers' onion varieties might be due to variation in genotypes, and better capacity to perform under the different agro-climatic condition [29], whereas keeping quality was found superior due to the thick-layer and compact skin of the bulbs. In agreement with present results, earlier studies also reported significant difference in maturity period and bulb yield among different onion varieties [20]. It is also reported that the bulb production and their keeping quality could be varied due to their different genetic make-up and agro ecological adaptations [21,30].

It was found that PDI correlated negatively and significantly with the bulb yield (r=-.96, p=.01), bulb weight (r=-.82, P=.05) and keeping quality (r=-.81, p=.05) (Table 7). In an earlier study of Nainwal and Vishunavat, (2016) showed correlation between the severities of the onion diseases with the yield [31]. Yadav et al. (2017) also reported highly significant negative correlation of purple blotch disease with bulb yield (r=-0.71, p=.01) and bulb size (r=-.67, p=.01) [32].

4. CONCLUSION

In the present study, it is confirmed that the purple blotch disease severely affects bulb yield, bulb weight and also keeping quality of the bulbs. Based on the findings, the farmers' onion cultivars *Sandip* and *Sona-40* may be cultivated under organic cultivation. Both the varieties are tolerant to the purple blotch disease and they may be used as parent material for crop improvement programs. Based on the present outcomes, both the varieties can be cultivated in onion growing areas of Maharashtra and Gujarat. These varieties may also give excellent production in the areas where purple blotch disease is very prominent.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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