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Studies on flowering induction, sex ratio and fruit set improvement in pomegranate

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ABSTRACT

The present study was conducted to induce flowering at the desired period with higher percentage of bisexual flowers and fruit set to improve yield and minimize fruit cracking through withholding of irrigation, pruning and ethrel application. Pooled data analysis revealed that horticultural interventions, chemical treatments and their interactions significantly affected sex ratio and fruit set. Among horticultural interventions, earliest defoliation (10.47 days), highest defoliation (81.25%), shortest flowering period (64.46 days), minimum male flowers (58.59%), maximum bisexual flowers (27.43%), maximum fruit set (25.84%) and fruit retention (82.23%) were recorded in withholding of irrigation during June + pruning and thinning as compared to control natural flowering. Among chemical treatments, earliest defoliation (7.59 days), highest defoliation (93.35%) and shortest flowering period (61.07 days) were recorded in ethrel 3 ml/l + DAP 5 g/l application while minimum male flowers (59.21%), maximum bisexual flowers (25.51%), maximum fruit set (25.16%) and fruit retention (80.74%) were recorded in ethrel 2 ml/l + DAP 5 g/l treatment as compared to control. Among interactions, earlier defoliation (6.78 days), highest defoliation (95.72%) and shortest flowering period (55.42 days) were observed in withholding of irrigation during June + pruning and thinning + ethrel 3 ml/l + DAP 5 g/l treatment. The minimum male flowers (57.78%), maximum bisexual flowers (28.22%), maximum fruit set (26.39%) and fruit retention (83.34%) were recorded in withholding of irrigation during June + pruning and thinning + ethrel 2 ml/l + DAP 5 g/l treatment as compared to maximum male flowers (66.36%), minimum bisexual flowers (22.03%), fruit set (22.19%) and fruit retention (75.28%) recorded in natural flowering without chemical treatment. Therefore, it can be concluded that withholding of irrigation during June + pruning and thinning + ethrel 2 ml/l + DAP 5 g/l treatment induced flowering during optimal climatic conditions and significantly improved sex ratio and fruit set of pomegranate.

Key words: *Punica granatum*, bisexual flower, flower regulation, water stress, ethrel.

INTRODUCTION

Pomegranate is an emerging fruit crop of hot arid regions. Pomegranate covers 2.62 lakh ha area with an annual production of 30.34 lakh tonnes and a productivity of 11.58 tonnes/ha in India (Anonymous, 3). Pomegranate produces flowers in three main seasons known as *ambe bahar* (January-February), *mrig bahar* (June-July) and *hasta bahar* (September-October). Only one *bahar* in a year is advisable for regulation of flowering and fruiting to maintain productivity and to get prolific harvest at a specific time. In assured rainfall areas (June-September), flowering in June-July is advantageous, while the areas where monsoon starts late in August, flowering during August is beneficial. Areas having assured irrigation facilities during April-May, flowering during January can be considered and where monsoon withdraws by September, induction of flowering in October is possible (Sachin *et al*., 13). In arid region, *mrig bahar* is preferred but fruits are severely damaged by cracking during December-January owing to diurnal temperature variation. Singh and Kingsly (16) reported that due to inferior colour development and quality of fruits, *ambe bahar* is not recommended in the arid and semi-arid climate. Moisture stress, plant bio-regulators, defoliants, nutrient and canopy management including training, pruning and thinning are major horticultural interventions that influence flowering and fruit quality in pomegranate (Kumar *et al*., 10). Water stress induces flowering during required period which could result in minimization of fruit cracking with improved fruit quality and yield. In pomegranate, 30-45 days of stress was imposed by the withholding of irrigation depending upon soil and climatic condition. Pruning and blossom thinning is performed to modify natural growth habits of pomegranate plant to manage needless vegetative growth and regulate flowering and fruiting for quality yield. Ethylene is engaged in the arrest of stamen development by the initiation of DNA damage, which promotes female flowers in some plant species. In hot arid climate, fruit cracking, low yield and inferior quality are major problems. Therefore, the present investigation was carried out

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to induce flowering during desired period in such a way that plant produces higher number of bisexual flower with improved fruit set which ultimately leads to improvement of yield, quality with minimum fruit cracking incidence by forcing plants to go into stress through withholding of irrigation, pruning and ethrel application.

MATERIALS AND METHODS

The present investigation was conducted at Research Farm of ICAR-Central Institute for Arid Horticulture, Bikaner during two consecutive years 2017-18 and 2018-19. There were two factors *i.e.* first factor included horticultural interventions (P) with five levels (P_0- control natural flowering, P_1- withholding of irrigation during March, P_2- withholding of irrigation during March + pruning and thinning, P_3- withholding of irrigation during June and P_4- withholding of irrigation during June + pruning and thinning) and second factor included chemical applications (C) with four levels (C_0- control without chemicals, C_1- ethrel 1 ml/l + DAP 5g/l, C_2- ethrel 2 ml/l + DAP 5g/l and C_3- ethrel 3 ml/l + DAP 5g/l) comprising 20 treatment combinations. The experiment was laid out in Factorial Randomized Block Design with three replications. Pruning of 20 cm growth was done after withholding of irrigation period. In thinning, flowers were removed before and during water stress period as per the treatments and only flowers which induced after treatment application were retained. Ethrel (40%) and DAP (18:46 grade) were applied as foliar spray after withholding of irrigation period and pruning as per treatments, while in natural flowering treatments (control treatment of the first factor) ethrel and DAP were applied in last week of May (30-31 May). The experiment was conducted on eight years old uniform plants of pomegranate cv. Jalore Seedless planted at 5x2.5 m^2 spacing under drip irrigation system. The recommended dose of fertilizers was applied and uniform intercultural operations were carried out to raise the crop. The mean monthly weather data during experimentation period are presented in Table 1. The soil of orchard was loamy sand with pH of 8.32 and electrical conductivity of 0.27 dSm^{-1}. It had 0.15% organic carbon, 106.4 kg/ha available nitrogen, 11.51 kg/ha available phosphorus and 214.5 kg/ha available potassium content. Data were recorded on days to defoliation, defoliation (%), days to flowering, flowering period, percentage of male, intermediate and bisexual flowers, fruit set and retention (%) and analyzed statistically as per the methods suggested by Gomez and Gomez (6).

RESULTS AND DISCUSSION

The data presented in Table 2 illustrated that horticultural interventions, chemical applications and their interaction significantly influenced days to defoliation in pomegranate. Among horticultural interventions, significantly minimum days to defoliation (10.19, 10.75 and 10.47) was registered in withholding of irrigation during June + pruning and thinning (P_4) treatment which was statistically at par with withholding of irrigation during June (P_3) treatment (10.31, 10.90 and 10.60) in the years 2017-18, 2018-19 and pooled basis, respectively. The maximum days to defoliation (13.10, 13.60 and 13.35) was recorded in control natural flowering (P_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively.

Table 1. Mean monthly weather condition prevailed during experimentation period.

Month	Temperature (°C)		Relative humidity (%)		Total rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
January	23.57	5.46	83.06	33.55	1.25
February	28.48	9.21	74.35	26.80	0.00
March	34.50	16.06	57.74	20.52	1.10
April	40.33	22.25	49.88	24.40	11.50
May	43.44	27.02	45.73	22.30	13.40
June	39.94	27.92	68.14	39.16	67.45
July	38.20	27.96	81.20	49.09	130.75
August	36.55	26.55	79.80	49.84	72.70
September	37.50	23.95	69.98	37.32	3.00
October	37.89	18.70	52.30	21.09	0.00
November	30.99	11.69	67.48	26.78	1.50
December	25.21	5.56	74.94	32.04	1.00

Table 2. Effect of flower regulation treatments on days to defoliation and defoliation (%).

Treatments	Days to defoliation			Defoliation (%)		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Horticultural interventions (P)						
P_0	13.10	13.60	13.35	60.79	64.64	62.71
P_1	11.75	12.06	11.90	67.36	70.47	68.91
P_2	11.64	11.72	11.68	68.96	71.09	70.02
P_3	10.31	10.90	10.60	77.36	78.79	78.08
P_4	10.19	10.75	10.47	81.59	80.90	81.25
SEm±	0.23	0.25	0.17	1.05	1.09	0.76
CD (5%)	0.67	0.72	0.48	3.01	3.12	2.13
Chemical applications (C)						
C_0	18.19	18.59	18.39	39.53	40.79	40.16
C_1	11.58	12.11	11.84	64.01	65.09	64.55
C_2	8.36	8.80	8.58	89.24	92.20	90.72
C_3	7.47	7.72	7.59	92.06	94.64	93.35
SEm±	0.21	0.23	0.15	0.94	0.97	0.68
CD (5%)	0.60	0.65	0.43	2.70	2.79	1.91
Horticultural interventions × Chemical applications (PxC)						
P_0C_0	21.50	21.89	21.70	12.89	13.78	13.33
P_0C_1	12.61	13.11	12.86	58.49	60.10	59.30
P_0C_2	9.44	10.17	9.81	83.73	91.66	87.70
P_0C_3	8.83	9.22	9.03	88.03	93.03	90.53
P_1C_0	18.78	19.47	19.12	31.11	33.46	32.28
P_1C_1	11.78	12.10	11.94	59.12	62.75	60.94
P_1C_2	8.78	9.00	8.89	89.15	91.03	90.09
P_1C_3	7.67	7.67	7.67	90.04	94.64	92.34
P_2C_0	18.44	17.78	18.11	32.16	34.79	33.48
P_2C_1	11.83	11.95	11.89	62.57	63.43	63.00
P_2C_2	8.56	9.17	8.86	88.78	91.70	90.24
P_2C_3	7.72	8.00	7.86	92.34	94.44	93.39
P_3C_0	16.17	16.67	16.42	58.32	59.74	59.03
P_3C_1	10.83	11.89	11.36	64.91	68.46	66.68
P_3C_2	7.83	8.17	8.00	91.72	91.91	91.81
P_3C_3	6.39	6.89	6.64	94.48	95.07	94.77
P_4C_0	16.05	17.17	16.61	63.15	62.20	62.67
P_4C_1	10.83	11.50	11.17	74.94	70.71	72.83
P_4C_2	7.17	7.50	7.33	92.84	94.70	93.77
P_4C_3	6.72	6.83	6.78	95.43	96.00	95.72
SEm±	0.47	0.51	0.34	2.11	2.18	1.51
CD (5%)	1.33	1.45	0.97	6.03	6.24	4.27

The different chemical applications significantly affected days to defoliation and significantly minimum days to defoliation (7.47, 7.72 and 7.59) was registered in ethrel 3 ml/l + DAP 5 g/l (C_3) treatment followed by ethrel 2 ml/l + DAP 5 g/l (C_2) treatment (8.36, 8.80 and 8.58) as compared to maximum days to defoliation (18.19, 18.59 and 18.39 days) recorded in control without chemicals (C_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively. Among interaction treatments, significantly minimum days to defoliation (6.39, 6.89 and 6.64) was recorded in withholding of irrigation during June + ethrel 3 ml/l + DAP 5 g/l (P_3C_3) treatment which was statistically at par with days to defoliation (6.72, 6.83 and 6.78) in withholding of irrigation during June + pruning and thinning + ethrel 3 ml/l + DAP 5 g/l (P_4C_3) treatment as compared to the maximum days to defoliation (21.50, 21.89 and 21.70) recorded in control natural flowering without chemical (P_0C_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively.

Among horticultural interventions, significantly highest defoliation (81.59, 80.90 and 81.25%) was recorded in withholding of irrigation during June + pruning and thinning (P_4) treatment which was followed by withholding of irrigation during June (P_3) treatment (77.36, 78.79 and 78.08%) as against minimum defoliation (60.79, 64.64 and 62.71%) recorded in control natural flowering (P_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively. Among chemical applications, maximum defoliation (92.06, 94.64 and 93.35%) was recorded in ethrel 3 ml/l + DAP 5 g/l (C_3) treatment which was followed by ethrel 2 ml/l + DAP 5 g/l (C_2) treatment (89.24, 92.20 and 90.72%) in comparison to the lowest defoliation (39.53, 40.79 and 40.16%) recorded in control without chemicals (C_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively. Among interaction treatments, highest defoliation (95.43, 96.00 and 95.72%) was recorded in withholding of irrigation during June + pruning and thinning + ethrel 3 ml/l + DAP 5 g/l (P_4C_3) treatment which was followed by and at par with withholding of irrigation during June with ethrel 3 ml/l + DAP 5 g/l (P_3C_3) treatment (94.48, 95.07 and 94.77%) in the years 2017-18, 2018-19 and pooled basis, respectively as against the lowest defoliation (12.89, 13.78 and 13.33%) recorded in control natural flowering without chemical (P_0C_0) treatment.

The earlier and higher defoliation with increased concentration of ethrel might be attributed to activated expression of gene encoding cell wall-degrading enzymes like cellulase and polygalacturonase which accelerated senescence and caused leaf shedding. These results are in close conformity with Sachin *et al.* (13) who reported 50-70% defoliation by water

stress and 90-100% defoliation by chemical induced stress in pomegranate. Similar results were also obtained by Shabany and Sharifi (14), Chandra *et al.* (4), Sheikh (15), Supe *et al.* (17), Korde (9) and Jhade *et al.* (8) who reported that increasing concentration of ethrel increased defoliation in pomegranate as compared to minimum in control.

The data presented in Table 3 divulged that horticultural interventions significantly affected days to flowering of pomegranate. Significantly minimum days to flowering (39.12, 39.65 and 39.39) was recorded in control natural flowering (P_0) treatment which was at par with withholding of irrigation during June (P_3) treatment (39.75, 39.96 and 39.85) in the years 2017-18, 2018-19 and pooled basis, respectively. The maximum days to flowering (59.56, 58.45 and 59.00) was recorded in withholding of irrigation during March + pruning and thinning (P_2) in the years 2017-18, 2018-19 and pooled basis, respectively. The different chemical applications significantly affected days to flowering and significantly minimum days to flowering (39.94, 40.31 and 40.13) was recorded in ethrel 1 ml/l + DAP 5 g/l (C_1) treatment as against maximum days to flowering (54.19, 54.50 and 54.35) recorded in control without chemicals (C_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively. Among interaction treatments, minimum days to flowering (30.39, 32.50 and 31.44) was recorded in control natural flowering + ethrel 1 ml/l + DAP 5 g/l (P_0C_1) treatment while maximum days to flowering (64.50, 64.33 and 64.42) was recorded in withholding of irrigation during March + pruning and thinning + ethrel 3 ml/l + DAP 5 g/l (P_2C_3) treatment in the years 2017-18, 2018-19 and pooled basis, respectively.

The horticultural interventions significantly affected flowering period of pomegranate. Significantly shortest flowering period (62.71, 66.21 and 64.46 days) was recorded in withholding of irrigation during June + pruning and thinning (P_4) treatment which was followed by withholding of irrigation during June (P_3) treatment (67.08, 64.88 and 65.98 days) in comparison to the longest flowering period (80.88, 81.21 and 81.04 days) recorded in control natural flowering (P_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively.

The different chemical applications significantly affected flowering period of pomegranate. Significantly shortest flowering period (61.57, 60.57 and 61.07 days) was recorded in ethrel 3 ml/l + DAP 5 g/l (C_3) treatment followed by ethrel 2 ml/l + DAP 5 g/l (C_2) treatment (68.57, 69.13 and 68.85 days) as against the longest flowering period (79.87, 81.00 and 80.43 days) recorded in control without chemicals (C_0) treatment in the years 2017-18, 2018-19 and pooled

Table 3. Effect of flower regulation treatments on days to flowering and flowering period.

Treatments	Days to flowering			Flowering period (days)		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Horticultural interventions (P)						
P_0	39.12	39.65	39.39	80.88	81.21	81.04
P_1	57.08	56.04	56.56	70.83	71.29	71.06
P_2	59.56	58.45	59.00	68.33	70.00	69.17
P_3	39.75	39.96	39.85	67.08	64.88	65.98
P_4	44.99	42.85	43.92	62.71	66.21	64.46
SEm±	0.40	0.41	0.29	1.18	1.07	0.79
CD (5%)	1.14	1.19	0.81	3.37	3.05	2.24
Chemical applications (C)						
C_0	54.19	54.50	54.35	79.87	81.00	80.43
C_1	39.94	40.31	40.13	69.87	72.17	71.02
C_2	46.86	44.73	45.80	68.57	69.13	68.85
C_3	51.41	50.01	50.71	61.57	60.57	61.07
SEm±	0.64	0.64	0.45	1.05	0.95	0.71
CD (5%)	1.82	1.82	1.27	3.01	2.73	2.00
Horticultural interventions × Chemical applications (PxC)						
P_0C_0	49.50	53.39	51.45	108.67	109.33	109.00
P_0C_1	30.39	32.50	31.44	77.17	78.50	77.83
P_0C_2	35.17	35.22	35.20	76.33	73.67	75.00
P_0C_3	41.44	37.50	39.47	61.33	63.33	62.33
P_1C_0	54.83	53.22	54.03	75.83	77.33	76.58
P_1C_1	51.94	51.17	51.56	74.17	76.33	75.25
P_1C_2	58.06	57.22	57.64	73.00	71.33	72.17
P_1C_3	63.50	62.56	63.03	60.33	60.17	60.25
P_2C_0	58.89	55.61	57.25	71.33	72.17	71.75
P_2C_1	53.50	52.33	52.92	68.17	70.00	69.08
P_2C_2	61.33	61.50	61.42	67.17	68.67	67.92
P_2C_3	64.50	64.33	64.42	66.67	69.17	67.92
P_3C_0	51.89	53.22	52.56	71.17	73.17	72.17
P_3C_1	31.05	32.33	31.69	69.67	64.50	67.08
P_3C_2	35.22	33.89	34.56	66.67	63.83	65.25
P_3C_3	40.83	40.39	40.61	60.83	58.00	59.42
P_4C_0	55.83	57.06	56.45	72.33	73.00	72.67
P_4C_1	32.83	33.22	33.03	60.17	71.50	65.83
P_4C_2	44.50	35.83	40.17	59.67	68.17	63.92
P_4C_3	46.78	45.28	46.03	58.67	52.17	55.42
SEm±	1.42	1.42	1.01	2.35	2.13	1.59
CD (5%)	4.07	4.07	2.83	6.74	6.10	4.47

basis, respectively. Among interaction treatments, significantly shortest flowering period (58.67, 52.17 and 55.42 days) was recorded in withholding of irrigation during June + pruning and thinning + ethrel 3 ml/l + DAP 5 g/l (P_4C_3) treatment as compared to the longest flowering period (108.67, 109.33 and 109.00 days) recorded in control natural flowering without chemical application (P_0C_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively. The longer flowering duration in control natural flowering treatment may be owing to staggered flowering in all three seasons *i.e. ambe*, *mrig* and *hasta bahars*. Korde (9) and Anawal *et al*. (2) reported that flowering period in pomegranate was reduced with increasing concentration of ethrel and longest flowering period was recorded in control treatment.

The data (Table 4) revealed that horticultural interventions significantly decreased male flowers in pomegranate. Significantly minimum male flowers (58.92, 58.25 and 58.59%) was recorded in withholding of irrigation during June + pruning and thinning (P_4) treatment which was followed by withholding of irrigation during June (P_3) treatment (60.13, 59.32 and 59.72%) in the years 2017-18, 2018-19 and pooled basis, respectively. The maximum male flowers (65.20 and 63.51%) was recorded in control natural flowering treatment (P_0) during 2017-18 and pooled basis, respectively while in the year 2018-19, maximum male flowers (62.88%) was recorded in withholding of irrigation during March (P_1) treatment.

The different chemical applications significantly affected male flowers of pomegranate. Significantly minimum male flowers (59.86, 58.56 and 59.21%) was obtained in ethrel 2 ml/l + DAP 5 g/l (C_2) treatment followed by ethrel 1 ml/l + DAP 5 g/l (C_1) treatment (60.90, 59.84 and 60.37%) as compared to maximum male flowers (63.59, 62.09 and 62.84%) recorded in control without chemical (C_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively. Among interaction treatments, significantly minimum male flowers (58.20, 57.05 and 57.63%) was recorded in withholding of irrigation during June + ethrel 2 ml/l + DAP 5 g/l (P_3C_2) treatment which was followed by and at par with withholding of irrigation during June + pruning and thinning + ethrel 2 ml/l + DAP 5 g/l (P_4C_2) treatment (58.05, 57.50 and 57.78%) in the years 2017-18, 2018-19 and pooled basis, respectively. The maximum male flowers (68.37, 64.34 and 66.36%) was recorded in control natural flowering without chemical (P_0C_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively.

The horticultural interventions significantly increased intermediate flowers in pomegranate. Significantly maximum intermediate flowers (15.13,

Table 4. Effect of flower regulation treatments on male and intermediate flowers.

Treatments	Male flowers (%)			Intermediate flowers (%)		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Horticultural interventions (P)						
P_0	65.20	61.81	63.51	13.08	15.21	14.15
P_1	63.63	62.88	63.25	12.86	13.14	13.00
P_2	60.19	59.48	59.84	15.13	15.43	15.28
P_3	60.13	59.32	59.72	14.33	14.72	14.52
P_4	58.92	58.25	58.59	14.46	13.51	13.99
SEm±	0.27	0.23	0.18	0.28	0.24	0.19
CD (5%)	0.77	0.66	0.50	0.80	0.70	0.52
Chemical applications (C)						
C_0	63.59	62.09	62.84	12.60	13.32	12.96
C_1	60.90	59.84	60.37	14.47	14.76	14.61
C_2	59.86	58.56	59.21	15.08	15.48	15.28
C_3	62.12	60.89	61.51	13.74	14.05	13.90
SEm±	0.24	0.21	0.16	0.25	0.22	0.17
CD (5%)	0.69	0.59	0.45	0.71	0.63	0.47
Horticultural interventions × Chemical applications (PxC)						
P_0C_0	68.37	64.34	66.36	9.96	13.27	11.61
P_0C_1	63.38	60.21	61.80	15.03	16.70	15.86
P_0C_2	62.15	59.62	60.88	15.52	16.89	16.21
P_0C_3	66.91	63.06	64.98	11.82	14.00	12.91
P_1C_0	64.90	64.29	64.60	12.30	12.35	12.33
P_1C_1	63.38	62.87	63.12	13.02	13.02	13.02
P_1C_2	62.08	61.01	61.54	13.61	14.48	14.05
P_1C_3	64.16	63.34	63.75	12.51	12.73	12.62
P_2C_0	62.18	61.26	61.72	13.80	14.13	13.96
P_2C_1	59.65	59.04	59.35	15.51	16.05	15.78
P_2C_2	58.81	57.64	58.22	15.90	16.28	16.09
P_2C_3	60.14	59.97	60.06	15.29	15.25	15.27
P_3C_0	62.36	61.39	61.87	12.86	13.38	13.12
P_3C_1	59.20	58.45	58.82	14.80	15.13	14.96
P_3C_2	58.20	57.05	57.63	15.87	16.23	16.05
P_3C_3	60.77	60.37	60.57	13.77	14.15	13.96
P_4C_0	60.13	59.16	59.64	14.07	13.47	13.77
P_4C_1	58.87	58.65	58.76	13.98	12.91	13.44
P_4C_2	58.05	57.50	57.78	14.50	13.50	14.00
P_4C_3	58.63	57.71	58.17	15.31	14.15	14.73
SEm±	0.54	0.46	0.36	0.56	0.49	0.37
CD (5%)	1.54	1.33	1.00	1.60	1.40	1.05

15.43 and 15.28%) was recorded withholding of irrigation during March + pruning and thinning (P_2) treatment while minimum intermediate flowers (12.86, 13.14 and 13.00%) was recorded in withholding of irrigation during March (P_1) treatment in the years 2017-18, 2018-19 and pooled basis, respectively. The different chemical applications significantly increased intermediate flowers in pomegranate. Significantly maximum intermediate flowers (15.08, 15.48 and 15.28%) was recorded in ethrel 2 ml/l + DAP 5 g/l (C_2) treatment followed by ethrel 1 ml/l + DAP 5 g/l (C_1) treatment (14.47, 14.76 and 14.61%) as against minimum intermediate flowers (12.60, 13.32 and 12.96%) recorded in control without chemicals (C_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively.

Among interaction treatments, during 2017-18, significantly maximum intermediate flowers (15.90%) was recorded in withholding of irrigation during March + pruning and thinning + ethrel 2 ml/l + DAP 5 g/l (P_2C_2) treatment while during 2018-19 and pooled basis, maximum intermediate flowers (16.89 and 16.21%) was recorded in control natural flowering + ethrel 2 ml/l + DAP 5 g/l (P_0C_2), respectively. During 2017-18 and pooled basis, significantly minimum intermediate flowers (9.96 and 11.61%) was recorded in control natural flowering without chemicals (P_0C_0), respectively while during 2018-19, minimum intermediate flowers (12.35%) was recorded in withholding of irrigation during March without chemicals (P_1C_0) treatment. Pawar (12) reported that pruning and thinning treatments decreased male flowers (%) and increased intermediate flowers (%) in pomegranate as compared to control treatment. Similarly, Ahire (1), Chaudhari and Desai (5), Goswami *et al.* (7) and Anawal *et al*. (2) reported that ethrel application decreased male flowers (%) and increased intermediate flowers (%) in pomegranate. The minimum male flowers in ethrel treatment might be attributed to the arrest of stamen development by the initiation of DNA damage.

The horticultural interventions significantly increased bisexual flowers in pomegranate (Fig. 1). Significantly maximum bisexual flowers (26.61, 28.24 and 27.43%) was recorded in withholding of irrigation during June + pruning and thinning (P_4) treatment which was followed by bisexual flowers (25.54, 25.97 and 25.75%) in withholding of irrigation during June (P_3) treatment in the years 2017-18, 2018-19 and pooled basis, respectively. The minimum bisexual flowers (21.71, 22.98 and 22.35%) was recorded in control natural flowering treatment (P_0) in the years 2017-18, 2018-19 and pooled basis, respectively. The different chemical applications significantly increased bisexual flowers in pomegranate. Significantly maximum bisexual flowers (25.06, 25.96 and 25.51%) was obtained in ethrel 2 ml/l + DAP 5 g/l (C_2) treatment followed by ethrel 1 ml/l + DAP 5 g/l (C_1) treatment (24.64, 25.40 and 25.02%) as against minimum bisexual flowers (23.82, 24.59 and 24.20%) recorded in control without chemicals (C_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively. Among interaction treatments, maximum bisexual flowers (27.44, 29.00 and 28.22%) was recorded in withholding of irrigation during June + pruning and thinning + ethrel 2 ml/l + DAP 5 g/l (P_4C_2) treatment which was followed by withholding of irrigation during June + pruning and thinning + ethrel 1 ml/l + DAP 5 g/l (P_4C_1) treatment (27.15, 28.44 and 27.80%) in the years 2017-18, 2018-19 and pooled basis, respectively. During 2017-18, minimum bisexual flowers (21.27%) was recorded in control natural flowering + ethrel 3 ml/l + DAP 5 g/l (P_0C_3) treatment while during 2018-19 and pooled basis, minimum bisexual flowers was recorded (22.39 and 22.03%) in control natural flowering without chemicals (P_0C_0) treatment, respectively.

The higher bisexual flowers in withholding of irrigation during June + pruning and thinning + ethrel 2 ml/l + DAP 5 g/l (P_4C_2) treatment in pomegranate might probably due to induced stress through withholding of irrigation and ethrel application. Pruning alter ratio of old and new growth, crop geometry, sap flow, distribution of photosynthetic compounds and encourages more flow of nutrients and water to the remaining shoots which produce more bisexual flowers. Ethylene arrests stamen development by the initiation of DNA damage, which promotes female flowers. Pawar (12) reported that pruning and thinning enhanced bisexual flowers percentage in pomegranate and minimum bisexual flowers percentage was recorded in control without pruning. These findings are in confirmation with Ahire (1), Chaudhari and Desai (5), Goswami *et al.* (7), Anawal *et al*. (2) and Supe *et al.* (17) who reported that application of ethrel enhanced percentage of bisexual flowers in pomegranate.

The data presented in Table 5 indicated that horticultural interventions, chemical applications and their interaction significantly influenced fruit set in pomegranate. Among horticultural interventions, significantly highest fruit set (25.82, 25.87 and 25.84%) was recorded in withholding of irrigation during June + pruning and thinning (P_4) treatment which was followed by withholding of irrigation during June (P_3) treatment (25.21, 25.37 and 25.29%) in comparison to the lowest fruit set (22.71, 22.77 and 22.74%) recorded in control natural flowering (P_0) treatment in the years 2017-18, 2018-19 and

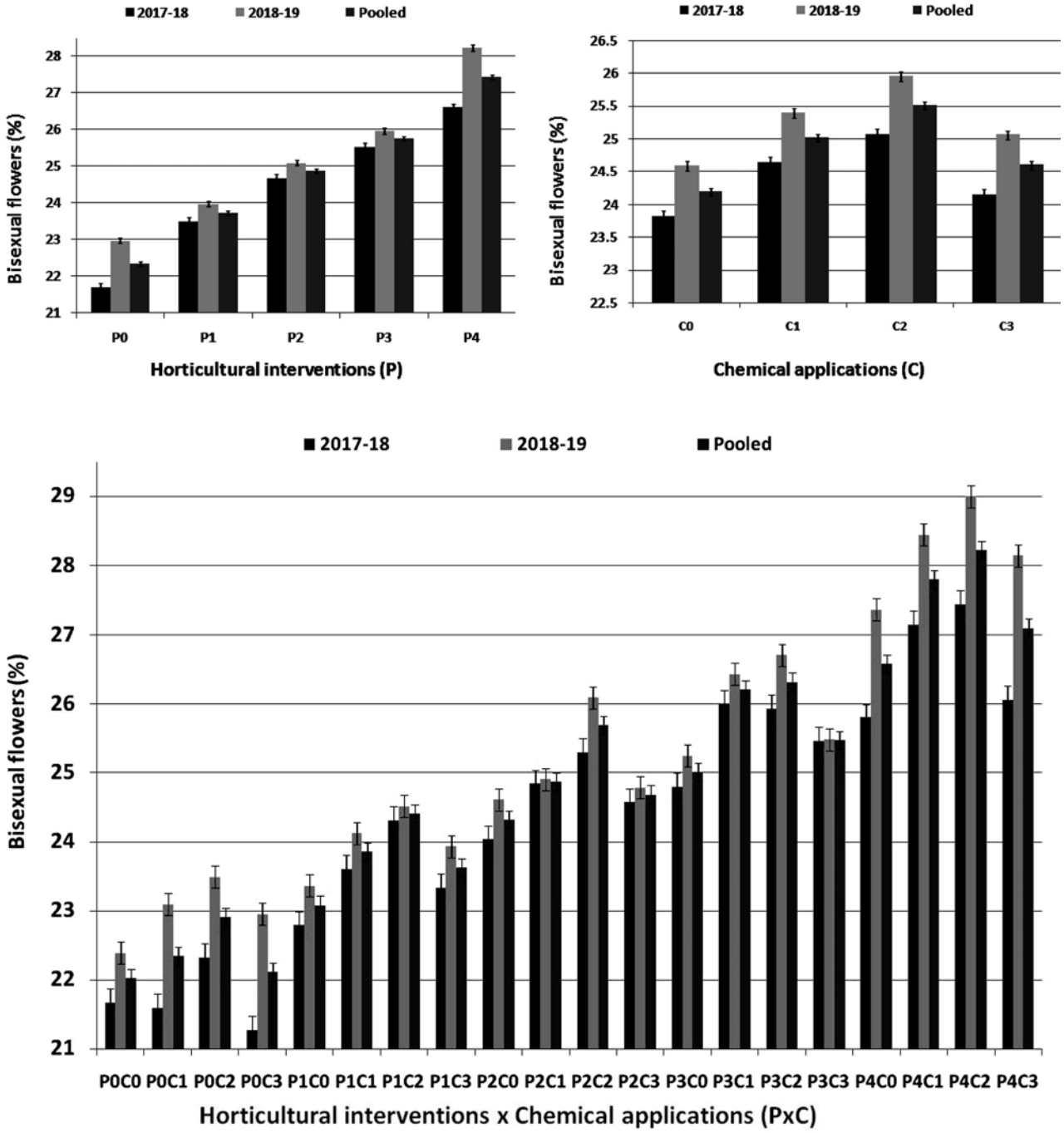

Fig. 1. Effect of flower regulation treatments on per cent bisexual flowers.

pooled basis, respectively. The different levels of chemical applications significantly influenced fruit set of pomegranate. Significantly highest fruit set (25.18, 25.14 and 25.16%) was recorded in ethrel 2 ml/l + DAP 5 g/l (C_2) treatment followed by ethrel 1 ml/l + DAP 5 g/l (C_1) treatment (24.75, 24.94 and 24.85%) as compared to lowest fruit set (24.05, 24.07 and 24.06%) recorded in control without chemicals (C_0) treatment during 2017-18, 2018-19 and pooled basis, respectively.

Among interaction treatments, the highest fruit set was recorded (26.26, 26.53 and 26.39%) in withholding of irrigation during June + pruning and thinning + ethrel 2 ml/l + DAP 5 g/l (P_4C_2) treatment which was statistically at par with withholding of irrigation during June + pruning and thinning + ethrel

Table 5. Effect of flower regulation treatments on fruit set and fruit retention.

Treatments	Fruit set (%)			Fruit retention (%)		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Horticultural interventions (P)						
P_0	22.71	22.77	22.74	76.53	76.54	76.54
P_1	24.18	24.14	24.16	77.67	81.26	79.47
P_2	24.72	24.81	24.77	78.64	81.43	80.03
P_3	25.21	25.37	25.29	77.67	81.29	79.48
P_4	25.82	25.87	25.84	81.10	83.36	82.23
SEm±	0.06	0.05	0.04	0.23	0.23	0.16
CD (5%)	0.17	0.14	0.11	0.66	0.67	0.46
Chemical applications (C)						
C_0	24.05	24.07	24.06	77.19	79.61	78.40
C_1	24.75	24.94	24.85	78.75	81.10	79.92
C_2	25.18	25.14	25.16	79.52	81.95	80.74
C_3	24.14	24.22	24.18	77.82	80.44	79.13
SEm±	0.05	0.04	0.04	0.20	0.21	0.15
CD (5%)	0.15	0.13	0.10	0.59	0.60	0.41
Horticultural interventions × Chemical applications (PxC)						
P_0C_0	22.10	22.29	22.19	75.61	74.95	75.28
P_0C_1	23.05	23.04	23.05	77.00	76.94	76.97
P_0C_2	23.53	23.34	23.44	77.66	78.74	78.20
P_0C_3	22.15	22.41	22.28	75.89	75.54	75.71
P_1C_0	23.78	23.80	23.79	76.43	80.20	78.31
P_1C_1	24.38	24.53	24.46	78.51	81.40	79.95
P_1C_2	24.67	24.37	24.52	78.71	82.57	80.64
P_1C_3	23.89	23.87	23.88	77.02	80.89	78.96
P_2C_0	24.20	24.10	24.15	77.69	80.24	78.97
P_2C_1	25.05	25.23	25.14	79.00	82.04	80.52
P_2C_2	25.34	25.48	25.41	79.87	82.47	81.17
P_2C_3	24.30	24.44	24.37	77.99	80.98	79.48
P_3C_0	24.79	24.85	24.82	76.83	80.37	78.60
P_3C_1	25.13	25.65	25.39	77.94	81.58	79.76
P_3C_2	26.08	25.97	26.03	78.89	81.78	80.34
P_3C_3	24.85	25.00	24.92	77.01	81.43	79.22
P_4C_0	25.37	25.33	25.35	79.41	82.32	80.86
P_4C_1	26.14	26.25	26.19	81.28	83.55	82.42
P_4C_2	26.26	26.53	26.39	82.49	84.19	83.34
P_4C_3	25.51	25.36	25.43	81.21	83.38	82.30
SEm±	0.12	0.10	0.08	0.46	0.47	0.33
CD (5%)	0.34	0.29	0.22	NS	NS	NS

1 ml/l + DAP 5 g/l (P_4C_1) treatment (26.14, 26.25 and 26.19%) as against the lowest fruit set (22.10, 22.29 and 22.19%) recorded in control natural flowering without chemical (P_0C_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively. Similarly, Pawar (12) and Ustad (18) obtained higher fruit set with increasing pruning intensity in pomegranate as compared to minimum in control. Korde (9) reported that application 0.2% ethrel increased fruit set in pomegranate and minimum recorded in control. Murthy (11) also reported that spraying of ethrel at 2 ml/l mixed with DAP 5 g/l in pomegranate increased fruit set percentage. The higher fruit set in withholding of irrigation during June + pruning and thinning with ethrel 2 ml/l + DAP 5 g/l (P_4C_2) treatment might be attributed to favourable climatic during flowering and production of more bisexual flowers by ethrel application which set more fruits in pomegranate.

The data (Table 5) illustrated that horticultural interventions and chemical applications significantly improved fruit retention of pomegranate while their interaction was found non significant in both the years and pooled basis. Among horticultural interventions, significantly highest fruit retention (81.10, 83.36 and 82.23%) was obtained in withholding of irrigation during June + pruning and thinning (P_4) treatment as compared to the lowest fruit retention (76.53, 76.54 and 76.54%) recorded in control natural flowering treatment (P_0) in the years 2017-18, 2018-19 and pooled basis, respectively.

Among chemical applications, significantly highest fruit retention (79.52, 81.95 and 80.74%) was recorded in ethrel 2 ml/l + DAP 5 g/l (C_2) treatment followed by ethrel 1 ml/l + DAP 5 g/l (C_1) treatment (78.75, 81.10 and 79.92%) as compared to the lowest fruit retention (77.19, 79.61 and 78.40%) recorded in control without chemicals (C_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively.

Among interaction treatments, highest fruit retention was recorded (82.49, 84.19 and 83.34%) in withholding of irrigation during June + pruning and thinning + ethrel 2 ml/l + DAP 5 g/l (P_4C_2) treatment which was followed by withholding of irrigation during June + pruning and thinning + ethrel 1 ml/l + DAP 5 g/l (P_4C_1) treatment (81.28, 83.55 and 82.42%) in the years 2017-18, 2018-19 and pooled basis, respectively. The lowest fruit retention was recorded (75.61, 74.95 and 75.28%) in control natural flowering without chemical (P_0C_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively.

The high fruit retention in withholding of irrigation during June + pruning and thinning + ethrel 2 ml/l + DAP 5 g/l (P_4C_2) treatment is probably due to favourable climatic condition during flowering and fruit development and reduction in fruit drop by ethrel

application. Similar findings were also obtained by Ahire (1) and Chakma (2014) who reported that pruning reduced fruit drop and enhanced fruit retention in pomegranate. Korde (9) reported that application 0.2% ethrel reduced fruit drop and improved fruit retention in pomegranate.

DECLARATION

The authors declare no conflict of interest.

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