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Original Research Paper

Breeding for Improvement of High Temperature Tolerance in Garden Pea (*Pisum sativum* L.) for off Season Cultivation

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ABSTRACT

The present investigation is aimed towards breeding varieties of garden pea for early summer cultivation (March-May) that can tolerate temperatures up to 35^{0}C. High temperature tolerant accessions KTP-4, Arka Sampoorna, Oregon Sugar, Magadi local were crossed with Arka Ajit, Arka Pramodh, Arka Priya having superior pod quality, yield and followed by pedigree method of breeding, superior transgressive segregants from these crosses were advanced up to F_7 generation. In F_7, six selected advanced breeding lines were assessed for their performance in the field with checks during early summer for four years in succession. Results revealed significant differences between selected lines and checks wherein all the lines surpassed checks with yield ranging from 5.9-7.6 t/ ha and in checks it was only 2.6-3.1 t/ha. Among these six breeding lines, three lines were selected based on high yield (6.7-7.6 t/ha), pod quality characters and identified to be highly suitable for early summer cultivation.

Key words: Breeding, Early summer, Garden pea, High temperature, Stress tolerance

INTRODUCTION

Globally, vegetable legumes are conventionally identified as indispensable sources of nutrition and health to humankind besides radically influencing agricultural sustainability. Garden pea, one among the commercially cultivated leguminous vegetables is a dense source of nutrients and vital source of health promoting antioxidants, minerals, vitamins and phytonutrients (Dahl *et al.* 2012). In India, garden pea is grown in an area of 0.55 million hectares (m.ha) with an annual production of 5.52 million tonnes (m.t) and productivity of 10.03 t/ha (NHB, 2018-19). Various factors are known to influence yield of which, abiotic stresses especially temperature, drought and salt stress take away major share in causing severe yield losses by impairing growth and development of plants in majority of the crop species(Suzuki *et al.,* 2014). Within these factors, temperature stress imposes most protracted effects on plant development and reproduction accompanied with severe reduction in yield potential of many subtle crop species (Bita and Gerats, 2013). Garden pea being extremely sensitive to temperature stress, if subjected to higher temperatures responds in an exacerbated manner resulting in drastic reduction of yield. This strictly hampers summer cultivation of the crop where there exists a great demand for peas during off season. Hence, in India it is traditionally cultivated during rabi season when the temperatures fall between 15 to 27^{0}C that highly favor crop growth and yield (Mohan *et al.,* 2013). Summer cultivation of the crop is restricted to high altitude areas where congenial conditions for crop growth exist and in plains cultivation during summer often influences principal morphological, physiological, biochemical and molecular plant processes in a sequential manner affecting the overall plant growth and productivity remarkably (Petkova *et al.* 2009; Todorova *et al.,* 2016). Among various growth phases of the crop, reproductive stage is highly vulnerable to elevated temperatures (>30^{0}C) affecting pollination, flower shedding, flower abortion, seed loss, pod filling and ultimately lowers the yield (Guilioni *et al.,* 2003; Bueckert *et al.,* 2015). In the recent years, demand for off season peas has enormously increased and is still anticipated to increase in the coming future owing to its nutritional and health benefits.To meet the ever growing demand for garden pea during off season, peas are often frozen and preserved for months together. Since the main growing season of the crop is confined to rabi, at present there are no commercial varieties of garden pea suitable for cultivation at least during early summer. Although varieties like Magadi local are cultivated during early summer on a commercial scale in certain parts of Southern India, being a pulse type (*arvense* group) with small pods its yields are exceedingly low with 2.5 t/ha. The realistic approach to surmount this barrier unequivocally includes initiation of breeding programmes to develop resilient varieties tolerant to high temperature (up to 35^{0}C) that could suit off season cultivation. With this objective, breeding work was started at ICAR-Indian Institute of Horticultural Research (IIHR), Bengaluru, India during 2007 and aimed towards development of high temperature tolerant varieties (33-35^{0}C) suitable for early summer cultivation.

MATERIALS AND METHODS

A field experiment was started in 2007 at Indian Institute of Horticultural Research, Bengaluru, India (13.13° N, 77.49° E) located at an altitude of 890 m above mean sea level. Initially, 200 pea germplasm lines of garden pea were screened for three consecutive years during summer 2007 to 2009 for identification of lines tolerant to high temperature. Average maximum and minimum temperatures recorded during the crop growth period were 35^{0}C and 26^{0}C respectively. Screening and selection of tolerant lines was based mainly on yield related traits such as pods per plant, pod filling, seeds per pod, shelling percent and yield *per se*. Among 200 lines screened, accessions KTP-4, Magadi local, Arka Sampoorna and Oregon sugar were identified to be tolerant to high temperature and performed superior in terms of yield and other related traits for three consecutive years. During 2009, selected high temperature tolerant lines were used as parents and crossed with high yielding varieties Arka Ajit, Arka Priya and Arka Pramodh having average pod yield of 10-12 t/ha to generate F_1 population. Initially, crosses were attempted between (Arka Ajit × Arka Sampoorna) and (Arka Pramodh × Oregon Sugar) separately and in the resultant segregating generation $F_{2,}$ superior lines derived from both the crosses were further crossed and advanced upto F_7 followed by pedigree method of breeding. Simultaneously in another cross, superior F_2 transgressive segregants developed from the cross (Arka Pramodh × Oregon Sugar) were selected and crossed to Arka Priya to improve pod filling and advanced up to F_7 generation followed by pedigree breeding. From both the crosses [(Arka Ajit × Arka Sampoorna) × (Arka Pramodh × Oregon Sugar)] and [(Arka Pramodh × Oregon Sugar) × Arka Priya], six advanced breeding lines were selected in F_7 generation during 2014 and were evaluated in randomized block design with three replications using three checks *viz.,* Magadi local (tolerant to high temperature), Arka Ajit and Arka Pramodh (high yielding) during summer for four consecutive years from 2014-2017. Standard package of practices was followed and no rainfall was received during the entire crop growth period. The maximum temperature recorded during reproductive and pod setting stages did not exceed 35^{0}C. Data on plant height, days to 50% flowering, pod length, pod width, 10 pod weight, pods per plant, seeds per pod, pod yield per plant, pod and seed color were recorded from 10 plants in each of the three replications. Data obtained was subjected to Analysis of variance (ANOVA) using the GENSTAT 9.1 package to assess significant differences among the breeding lines and checks based on mean performance.

RESULTS AND DISCUSSION

Results of ANOVA revealed significant differences among different advanced breeding lines for various morphological, yield and yield related traits in the present study (Table 1). The average plant height in the advanced breeding lines ranged from 64.0 to 127.0 cm. Highest plant height of 127.0 cm was recorded in the line IIHR 12-3 followed byIIHR 15-21 with 126.7 cm and least of 57.3 cm was reported in check variety Arka Ajit. Days taken for 50% flowering in the lines ranged from 44.0 to 48.3 as compared to checks with 42.3 to 48.7 days. With respect to this trait, lowest of 42.3 days was reported in check Magadi local followed by IIHR 15-6 with 44 days and highest of 48.7 days was recorded in Arka Pramodh. In connection to days to pod maturity, variability in the lines ranged from 60.0 to 65.7 and in checks it was 58.3 to 65.0 days. This clearly illustrates that no significant difference exist between lines and checks for the two traits *viz*., days to 50% flowering and days to pod maturityand all the selected breeding lines fit into the category of mid-season varieties that can arrive to pod maturity within 60-65 days of flowering. With respect to pod length and width, selected breeding lines had higher pod length ranging from 6.5 to 7.9 cm and width of 1.4 to 1.6 cm in comparison to checks with pod length and width of 4.2 to 6.7 cm and 1.2 to 1.6 cm respectively. In terms of pod length, highest of 7.9 cm was observed in IIHR 15-6 followed by IIHR 15-21 with 7.0 cm and least of 4.2 cm was found in check Magadi local. Similar trend was reported in case of pod width wherein IIHR 15-6 followed by IIHR 1-1 recorded highest pod width of 1.6 cm and 1.5 cm respectively and lowest of 1.2 cm was recorded by check Magadi local.

Table 1. Mean performance of selected lines and checks for plant and pod characters during summer (2014-2017)

S.No.	Advanced breeding lines & checks	Plant height (cm)	Days to 50 % flowering	Days to pod maturity	Pod length (cm)	Pod width (cm)	10 pod wt.(g)	Shelling %	Seeds per pod	Pods per plant	Pod & seed colour
1.	IIHR 15-6	67.7	44.0	60.3	7.9	1.6	63.7	56.0	7.7	16.3	DG
2.	IIHR 1-2	64.0	48.0	65.0	6.8	1.5	55.7	56.3	6.3	15.0	DG
3.	IIHR 1-1	65.7	48.3	65.7	6.9	1.5	55.0	57.0	6.3	14.0	DG
4.	IIHR 15-21	126.7	45.3	64.0	7.0	1.4	57.3	60.0	7.3	17.0	G
5.	IIHR 12-3	127.0	45.0	60.0	6.5	1.4	37.7	54.0	5.7	17.7	LG
6.	IIHR 15-15	124.3	45.7	62.3	7.0	1.4	55.7	58.3	6.7	22.3	DG
7.	Magadi local (C)	122.3	42.3	58.3	4.2	1.2	23.3	57.0	4.3	24.0	LG
8.	Arka Ajit (C)	57.3	46.3	64.0	6.7	1.4	43.0	34.3	3.0	10.0	LG
9.	Arka Pramodh (C)	58.0	48.7	65.0	6.7	1.6	42.3	25.0	2.0	8.0	DG
	S.E.(m) ±	2.59	1.03	0.82	0.16	0.04	2.14	1.30	0.49	1.05	
	CD@5%	7.19	2.85	2.27	0.44	0.11	5.92	3.59	1.36	2.90	
	CV%	4.10	3.17	1.84	3.33	3.45	6.27	3.60	12.59	6.55	

DG-Dark Green, LG-Light Green, G-Green, C-Check variety

Among traits governing yield such as pod weight, shelling percent, number of pods per plant and number of seeds per pod significant differences in mean values were observed between checks and selected advanced breeding lines.With respect to 10 pod weight, all the selected lines recorded significantly higher pod weight ranging from 37.7 to 63.7 g as compared to checks with 23.3 to 43.0 g. Highest pod weight of 63.7 g was recorded in IIHR 15-6 and lowest of 23.3 g in check Magadi local. All the breeding lines except IIHR 12-3 (37.7 g) performed significantly superior than all the checks for this specific trait. Concurrent to this, shelling percent was also found to be high in the selected lines ranging from54 to 60% as compared to checks with 25 to 57%. Results from mean of shelling percent revealed highest performance in the line IIHR 15-21 (60%) followed by IIHR 15-15 (58.3%) and least of 25% was recorded in check variety Arka Pramodh. Further, number of seeds per pod in the selected lines were markedly higher ranging from 5.7 to 7.7 as compared to checks with only 2.0 to 4.3 seeds per pod. For this respective trait, IIHR 15-6 followed by IIHR 15-15 were found to have more seeds per pod with 7.7 and 6.7 respectively than checks. These results emphasize that pollination in check varieties was critically impaired due to exposure to high temperature eventually leading to seed abortion and lesser number of seeds with smaller size. The observed results were in accordance with the findings of few authors who reported lesser seed number and size in case of field pea after exposure to higher temperatures (Lambert and Linck, 1958; Jeuffroy *et al.*, 1990; Poggio *et al.,*2005). In contrast to this, for the trait pods per plant resistant check Magadi local reported highest of 24 pods whereas temperature sensitive high yielding check Arka Pramodh had lowest of 8 pods per plant. Elsewhere, in the selected lines it ranged from 14.0 to 22.3 wherein IIHR 15-15 and IIHR 1-1 recorded highest of 22.3 pods per plant and lowest of 14.0 pods per plant respectively. The reason behind abruptly low number of pods per plant in case of high yielding checks Arka Ajit (10.0) and Arka Pramodh (8.0) could be directly attributed to lack of high temperature stress tolerance. Similar trend of decline in yield of heat susceptible cultivars has been reported in case of bean (*Phaseolus vulgaris*) by exposing plants to higher day temperatures of more than 28^{0}C (Prasad *et al.,* 2002). Although tolerant check is performing superior with respect to this trait, yield was on the higher side in selected advanced breeding lines owing to increased pod weight and more seeds per pod as compared to tolerant check. Further, comparison of yield *per se* between checks and selected breeding lines over average of four years were convincing and disclosed significant differences between checks and breeding lines with selected lines dominating and out yielding all the three check varieties. Average pod yield based on mean of four years in selected lines ranged from 5.9-7.6 t/ha in selected lines and in checks it was significantly lower with 2.6 to 3.1 t/ha. Among the six advance breeding lines, highest yield of 7.6 t/ha was reported in IIHR 15-15 followed by IIHR 15-21 with 7.1 t/ha and IIHR 15-6 with 6.7 t/ha(Table 2). All the three checks recorded significant reduction in yield levels that could be ascribed to effects of heat stress which potentially evoked flower drop, reduction in reproductive phase, reduced pod filling, abortion of seeds within pods finally lowering yield. In agreement to this, decline in yields of field pea cultivars due to high temperature stress was previously reported by Guilioni *et al.* (1997), Vijaylaxmi (2013) and Bueckert *et al.* (2015). Eventhough all the six selected breeding lines were reported to be superior over checks, three lines *viz.*, IIHR 15-15, IIHR 15-21 and IIHR 15-6 proved to be outstanding owing to minimal reduction in yield when exposed to higher temperatures in comparison to others. Further, percent increase in yield over lowest yielding check was reported to be 192.3% (IIHR 15-15), 173.1% (IIHR 15-21) and 157.7% (IIHR 15-6) in these three lines. Additionally, the three selected breeding lines were also superior in terms of pod qualitycharacteristics such as colour along with other yield attributing traits and released as Arka Uttam, Arka Chaitra and Arka Tapas respectively.

Table 2. Mean performance of selected breeding lines for pod yield (t/ha) during summer 2014 to 2017

Sl. No.	Advanced breeding lines and checks	2014 Summer mean	2015 Summer mean	2016 Summer mean	2017 Summer mean	Average	Per cent increase over check
1.	IIHR 15-6	6.6	6.7	6.6	6.9	6.7	157.7
2.	IIHR 1-2	6.2	6.0	5.9	6.3	6.1	134.6
3.	IIHR 1-1	5.9	5.9	5.6	6.0	5.9	126.9
4.	IIHR 15-21	7.1	7.1	6.9	7.3	7.1	173.1
5.	IIHR 12-3	7.0	6.9	6.6	6.9	6.9	165.4
6.	IIHR 15-15	7.6	7.5	7.3	7.8	7.6	192.3
7.	Magadi local (C)	2.6	2.6	2.4	2.8	2.6	-
8.	Arka Ajit (C)	3.1	3.0	2.7	2.8	2.9	-
9.	Arka Pramodh (C)	2.7	3.3	3.0	3.2	3.1	-
	S.E (m)±	0.18	0.15	0.17	0.18		
	CD@5%	0.51	0.42	0.47	0.49		
	CV%	4.80	3.90	4.60	4.49		

IIHR 15-6, IIHR 15-15 and IIHR 15-21 are selected advanced breeding lines identified for release as high temperature tolerant varieties.

These findings clearly illustrate that current breeding programme aimed towards incorporation of high temperature tolerance (33-35^{0}C) followed by rigorous selection procedures could successfully integrate heat stress tolerant genes into the selected lines as obvious from the results obtained from the study. Further, the average yield obtained from the lines during off season cultivation *i.e.,* summer was more than double in comparison to stress tolerant and high yielding checks. Even though yield (6.7-7.1 t/ha) obtained is not on par with the actual yields that could be realized from high yielding cultivars (10-12 t/ha) during normal season of cultivation *i.e.,* rabi, existing gap in yield levels can be compensated by the higher prices fetched for summer peas. Hence, the three varieties generated from this breeding programme invariably suit for cultivating garden pea in off season preferably during early summer in regions where temperatures donot exceed 35^{0}C. Further, the breeding material generated from the study tend to serve as base material for accomplishing in depth investigations on physiological and molecular mechanisms involved in regulating tolerance to high temperature in garden pea in the coming future.

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