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Pod setting behavior and harvest index of pigeonpea (*Cajanus cajan* L. Millsp.)

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Abstract
Pigeonpea is one of the major grain legumes consumed for human diet in Asian and African countries. It is of prime importance to study the pod set and harvest index of this crop as these characters are directly correlated to yield. Pigeonpea genotypes of different duration groups *viz*., extra early (APK 1, Vamban 1, Vamban (Rg) 3, CORG 9060, ICPL 83024 and ICPL 87109 of 100 days), early (Co 5, Co (Rg) 7, ICPL 83027, UPAS 120, CORG 200401 and CORG 200402 of 120-130 days) and medium (Co 6, Vamban 2, ICPL 87119, LRG 41, CORG 990014 and CORG 990015 of 180 days) were studied for their pod setting behavior and Harvest Index (HI). There was significant difference for total opened flowers among the genotypes of the different duration groups but the flower shedding and pod set per cent were constant. The pod set per cent ranged from 6.6 to 9.7 in the pigeonpea genotypes. The HI of extra early genotypes was between 33.1 to 41.0 per cent and in early genotypes it was 27.6 to 34.1.The medium duration genotypes recorded very low HI of 20.4 to 24.1 per cent. Negative correlation was observed between HI and duration of the crop. Pod set per cent was comparatively higher in male sterile lines (10.1 to 11.8) which may be due to slow and continued pod set which is enhanced by the insect pollinators.

Keywords: Pod set, harvest index, male sterile lines, pigeonpea

Introduction
In India pigeonpea genotypes with indeterminate, determinate and semi determinate growth habits are grown. In indeterminate types the flowering period is often prolonged enabling the plant to recover from various stresses such as temperature fluctuations, terminal drought, insect attack, etc. In Pigeonpea, it is studied that the plant produces a large amount of photosynthates but less than 20 per cent of it is consumed in producing the seeds and the remaining dry matter is conserved within the plant to support its life system under unfavorable condition. (Chauhan *et al*. 1987) [2]. Sheldrake and Narayanan (1979) [19] also demonstrated that in pigeonpea, the grain yield was not limited by the nutrient supply but it is a direct consequence of the number of pod set on a plant. Therefore, the pod setting on an individual plant stops when its food reserves fall below a threshold, such threshold level are not permanent and may vary from a cultivar to another cultivar and within a season depending on the prevailing macro/ micro environmental conditions. Pod setting percentage is negatively correlated with the flower drop (Remanandan, 1990) [16].
Grain yield is the integrated outcome of various physiological processes which constitute growth and development from germination to maturity. When the reproductive ontogeny is considered harvest index (HI) also goes along with it. Harvest index as reported is negatively correlated with days to 50% flowering, days to maturity, plant height, 100 seed weight and grain yield. Therefore, the present investigation was taken up to assess whether there exists any difference in pod setting behavior and harvest index between the genotypes of different duration groups within and between seasons and to assess the variation for pod setting pattern and harvest index between varieties and different male sterile lines of pigeonpea.

Material and Methods
In order to study the differences between the different duration groups of pigeonpea for pod setting behaviour and harvest index eighteen lines were selected. (Table 1). These genotypes were raised in four rows of four metres length with three replications in RBD following all the recommended management practices during *Kharif* at Department of Pulses, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore under irrigated condition.

In extra early duration group, five plants each per replication were selected on 63rd day. Similarly, five plants each were selected in early and medium duration groups on 79th and 110th days, respectively. The observations *viz.,* total number of flowers opened, number of dropped flowers were recorded for 21, 27 and 50 days for the extra early, early and medium genotypes, respectively. During harvest, number of pods, days to maturity, total biological yield and grain yield were recorded. The experiment was repeated with the extra early and early duration genotypes during summer season, as the medium genotypes are photosensitive and can be sown only during *Kharif*. The observations were recorded as previous season from 58 th and 70 th day on extra early and early genotypes for 17 and 21 days respectively. The data on total opened flowers, ineffective flowers, flowers developed into pods, days to maturity, total biological yield and grain yield were recorded. The flower shedding (%), pod set (%) and harvest index (%) were estimated.

In order to understand whether there exists any difference between the varieties and male sterile lines with respect to pod set and harvest index, the varieties *viz.,* Co 5, Co (Rg) 7, ICPL 83027, UPAS 120, genetic male sterile lines *viz.,* ms Co 5, ms T 21, ms ICPL 83027 and ms ICPL 83024 and cytoplasmic genetic male sterile lines *viz.,* CORG 990052A, CORG 990047A, CORG 990040A and GT 288A around 130 days duration were selected. The trial was laid out separately in RBD with five replications during the subsequent *Kharif* under irrigated condition. The genetic male sterile lines and cytoplasmic genetic male sterile lines were allowed for open pollination. The data on total opened flowers, ineffective flowers, flowers developed into pods, days to maturity, total biological yield and grain yield were recorded. The flower shedding (%), pod set (%) and harvest index (%) were estimated.

Results and Discussion

In pigeonpea, usually flowering may be confined to three weeks period or may continue for several months, depending on genotype, environmental conditions and sowing density Sheldrake *et al*. 1979 [18]; Meekin *et al.* (1987) [10]. However, severe drought stress will restrict both the duration and extent of flowering and pod formation. In the present study, the flowering was observed for 21, 27 and 50 days in the extra early, early and medium duration types, respectively. But from the crop of two seasons it was inferred that the weather parameters (season) play a vital role in flower initiation, flowering period on both extra early and early duration pigeonpea genotypes though they are inherited traits. The extra early genotypes produce on average 760 flowers in 21 days, while the early ones produce 1094 flowers in 27 days and the medium types produce 1614 flowers in 50 days (Table 2). Though more flowers were produced with increased duration the pod set per cent remains constant during *kharif.* While during summer, the flowering was observed for 17 and 21 days only in extra early and early genotypes. There was comparatively less number of flowers and low pod set observed during summer (Table 3 and Table 4). But when harvest index was observed for extra early genotypes it was 33.1 to 41.0 per cent followed by the early genotypes (27.6 to 34.1 per cent), while the medium duration genotypes recorded very low harvest index. Higher harvest index is observed in early genotypes.

Pigeonpea produces many flowers of which 90 per cent are shed without setting pods (Pathak (1970) [12]: Ariyanayagam (1975) [1]: Sheldrake *et al* (1979) [18]; and Pandey and Singh (1981) [11]. In the present investigation, it was inferred that there was no significant difference between extra early, early and medium duration genotypes for pod set per cent. The number of pods per plant is strongly related to assimilation during extra early pod growth, through effects on pod formation, for the first two weeks after anthesis, and on pod retention, for the next two weeks (Thirathon *et al* 1987) [20]. It is studied that a proportion of the carbon assimilated during pod growth is diverted to stems and other storage organs (Rawson and Constable (1981) [15]; Deshpande and Nimbalkar (1982) [3]; Setter *et al*.1984) [17];. It may also conserve a proportion of the assimilates produced during reproductive growth to support subsequent root and shoot growth (Sheldrake and Narayanan, 1979) [19];. It has been suggested that there may be vascular limitations to the supply of assimilates to the pods during the peak pod setting period.

In this experiment, it was observed that pod set per cent of the selected genotypes of different duration was between 8.4 to 9.4 during *kharif* and 6.6 to 9.7 during summer season. The flower shedding was comparatively high during summer because of the coincidence of high maximum temperature during day time. The probable physiological reasons are to be widely studied to control the flower shedding in this crop.

When the pod setting behaviour of varieties, genetic and cytoplasmic genetic male sterile lines were noted it was observed that there exists difference in the pod set per cent (Table 5). Also when the flowering and pod formation period was observed, there was a lot of difference. In the varieties, most pods develop from the first flush of flowers and almost attain their potential pod set. The majority of the late emerging flowers dropped even after their fertilization. These events were directly linked to the source – sink relationships. On the other hand, in both genetic and cytoplasmic genetic male sterile line plants, the initial pod set was low because they are dependent on the number of the insect pollinators *viz.*, *Melipona* sp. (Dammer bee), *Aphis florea* (honey bee), *Megachile* sp. (leaf cutter bee), *Anthophorid sp*, *Xylocopidae* sp. (yellow banded bee and carpenter bee) and *Danaius* sp. (*Calotropis* butterfly), wind direction and velocity, field location, temperature, relative humidity of that region (Rathnaswamy *et al*. 1997; Rathnaswamy *et al*.1998; Kalaimagal, and Ravikesavan. (2003); Kalaimagal and Muthiah (2004); Kalaimagal *et al* (2008a); Kalaimagal *et al* (2008b); Durairaj *et al* 2009; Kalaimagal *et al* (2012) [13, 14, 7, 6, 5, 8, 4, 9]. The pod set on the male sterile plants initially was very low, which permitted the formation of additional pods with subsequent pollinations. The process of insect dependent pod setting on the male sterile plants was slow and continued for a relatively longer period to reach their threshold level. The slow pod setting perhaps also enhanced the threshold capacity of the male sterile plants that allow them to hold more pods.

Harvest index is the proportion of total biomass and economic yield. Most importantly, the harvest index is a function of the relative duration of the vegetative and reproductive phase and during reproductive phase, the relative partitioning of current assimilate and the degree of remobilization of stored assimilate to seeds. Thus HI was particularly enhanced where the duration of reproductive growth represents a large proportion of total growth. In extra early genotypes HI of 33.1 to 41.0 per cent was observed followed by the early types (27.6 to 34.1 per cent) while, the medium duration genotypes recorded very low HI of 20.4 to 24.1 per cent. Therefore, when selection is made for increased harvest index the early genotypes get selected and *vice versa*. There is frequent negative relationship between HI and crop duration observed in pigeonpea.

It can be concluded that there exists significant difference between the pigeonpea genotypes for the total number of opened flowers while, for pod *set all* are on par. The flowering and pod setting are widely affected by the environmental conditions. The possible physiological causes of enhanced flowering and pod set in the male sterile lines have to be studied. Investigations aiming for reduced flower shedding have to be taken. The increase in pod setting per cent will naturally increase the harvest index of this crop.

Table 1: Pigeonpea genotypes taken for investigation

Duration group	Cultivars
Extra early (100 days)	APK 1, Vamban 1, Vamban (Rg) 3, CORG 9060, ICPL 83024 and ICPL 87109
Early (120-130 days	Co 5, Co (Rg) 7, ICPL 83027, UPAS 120, CORG 200401 and CORG 200402
Medium (180 days)	Co 6, Vamban 2, ICPL 87119, LRG 41, CORG 990014 and CORG 990015

Table 2: Pod setting behavior and harvest index of pigeonpea genotypes – *kharif* season

Genotypes	Total opened flowers	Ineffective flowers (shed etc.)	Flowers developed into pods	Flower shedding %	Pod set %	Harvest index %	Days to maturity	Grain yield Kg/ha
Extra early duration group (100 days)								
APK 1	680	620	60	91.2	8.8	33.1	102	870
Vamban 1	775	709	66	91.5	8.5	38.0	104	860
Vamban (Rg) 3	845	774	71	91.6	8.4	34.1	105	870
CORG 9060	712	650	62	91.3	8.7	41.0	98	720
ICPL 83024	857	785	72	91.6	8.4	33.3	98	820
ICPL 87109	691	630	61	91.2	8.8	40.1	98	760
Mean	760.0	694.7	65.3	91.4	8.6	36.6	100.3	816.7
CD	10.3	17.4	6.7	1.25	1.2	1.0	30.2	12.2
Sed	26.5	44.8	17.11	3.0	3.0	2.7	77.7	31.2
Early duration group (120-130 days)								
Co 5	1072	974	98	90.9	9.1	27.6	128	1050
Co (Rg) 7	1180	1075	105	91.1	8.9	34.1	120	1150
ICPL 83027	1061	967	94	91.1	9.9	34.0	126	980
UPAS 120	1011	921	90	91.1	8.9	33.2	122	920
CORG 200401	1065	1059	106	90.9	9.1	28.1	128	1050
CORG 200402	1077	979	98	90.9	9.1	28.3	127	1010
Mean	1094.3	995.8	98.5	91.0	9.0	30.8	125.2	1026.7
CD	103.6	103.4	3.1	2.0	2.0	1.6	4.9	66.6
Sed	266.2	265.9	7.9	5.1	5.1	4.1	171.2	12.5
Medium duration group (180 days)								
Co 6	1758	1598	160	90.9	9.1	20.4	178	1860
Vamban 2	1152	1046	106	90.8	9.2	20.6	188	1620
ICPL 87119	1318	1198	120	90.9	9.1	20.9	183	1580
LRG 41	1728	1569	159	90.8	9.2	22.0	178	1890
CORG 990014	1858	1674	184	90.1	9.9	24.1	180	2050
CORG 990015	1875	1702	173	90.8	9.2	23.2	180	2000
Mean	1614.8	1464.5	150.3	90.7	9.3	21.9	181.2	1833.3
CD	268.7	79.8	24.0	1.53	1.4	2.6	120.5	14.6
Sed	690.7	205.2	61.8	3.9	3.7	6.7	309.9	37.5
Comparison of different duration groups								
CD	113.02	102.6	10.7	0.12	0.12	1.59	11.19	78.36
Sed	251.82	228.6	23.7	0.28	0.29	3.56	24.93	174.6
Significance	**	**	**	NS	NS	**	**	**

Table 3: Pod setting behaviour and Harvest index of pigeonpea genotypes –Summer season

Genotypes	Total opened flowers	Ineffective flowers (shed etc.)	Flowers developed into pods	Flower shedding %	Pod set %	Harvest index %	Days to maturity	Grain yield Kg/ ha
Extra early duration group (100 days)								
APK 1	658	606	52	92.1	7.9	34.1	96	820
Vamban 1	750	689	61	91.9	8.1	38.2	97	790
Vamban (Rg) 3	802	736	66	91.8	8.2	34.3	94	820
CORG 9060	658	605	53	91.9	8.1	38.9	92	700
ICPL 83024	813	759	54	93.4	6.6	36.3	92	760
ICPL 87109	649	596	53	91.8	9.2	40.4	92	710
Mean	720.3	665.2	56.5	92.2	8.0	37.0	93.8	766.7
CD	129.7	121.3	11.8	2.4	2.6	3.6	2.8	98.7
Sed	333.5	311.9	30.4	6.3	6.7	9.3	7.3	6.74

Early duration group (120-130 days)								
Co 5	1025	937	88	91.4	8.6	26.2	118	920
Co (Rg) 7	1125	1027	98	91.3	8.7	28.1	112	940
ICPL 83027	1075	958	137	89.1	9.7	34.1	118	890
UPAS 120	960	876	84	91.3	8.7	33.2	115	830
CORG 200401	1007	919	88	91.3	8.7	34.1	118	910
CORG 200402	1012	925	87	91.4	8.6	30.2	116	905
Mean	1034.0	940.3	97.0	91.0	8.7	31.0	117.2	899.2
CD	100.2	29.6	17.9	2.3	2.3	3.1	3.7	135.5
Sed	257.7	76.2	38.3	5.9	5.9	7.9	9.5	348.5
Comparison of two duration groups								
CD	28.95	29.48	6.16	0.39	0.46	1.69	1.56	17.78
Sed	74.42	75.79	15.83	1.01	1.19	4.36	4.02	45.72
Significance	**	**	**	*	NS	*	**	**

Table 4: Analysis for seasonal variation for pod setting and harvest index in extra early and early genotypes of Pigeonpea

Genotypes	Total opened flowers	Ineffective flowers (shed etc.)	Flowers developed into pods	Flower shedding %	Pod set %	Harvest index %	Days to maturity	Grain yield Kg/ ha
Extra early duration group (100 days)								
CD	5.0	4.8	2.0	0.2	0.2	0.7	7.0	0.8
Sed	12.9	12.2	5.0	0.5	0.5	1.7	18.1	2.1
Significance	**	**	**	*	NS	NS	**	**
Early duration group (120-130 days)								
CD	22.6	18.1	158.1	0.4	13.3	1.6	17.9	0.6
Sed	58.2	46.5	408.5	1.0	34.1	4.2	46.0	1.6
Significance	*	*	NS	NS	NS	NS	**	**

Table 5: Pod setting behaviour and Harvest index of pigeonpea varieties, genetic and cytoplasmic genetic male sterile lines during *kharif season*

Genotypes	Total opened flowers	Ineffective flowers (Shed etc.)	Flowers developed into pods	Flower shedding %	Pod set %	Harvest index %	Days to maturity	Grain yield Kg/ ha
Varieties								
Co 5	1050	950	100	90.5	9.5	27.1	128	1040
Co (Rg) 7	1173	1072	111	91.4	8.6	32.1	121	1180
UPAS 120	1049	953	90	90.8	9.2	34.0	125	900
ICPL 83027	1015	928	96	91.4	8.6	33.3	124	930
Mean	1071.7	975.8	99.3	91.0	9.0	31.6	124.5	1012.5
CD	100.2	57.1	16.8	1.5	1.2	2.7	36.8	53.4
Sed	318.9	181.7	53.3	4.6	3.9	8.5	116.9	169.9
Genetic male sterile lines								
ms Co 5	1369	1218	151	89.0	11.0	29.2	135	1180
ms T 21	1380	1242	138	90.0	10.0	34.3	136	1100
ms ICPL 83027	1368	1220	148	89.2	10.8	29.5	134	970
ms ICPL 83024	1110	992	118	89.4	10.6	30.5	134	940
Mean	1306	1168	138.8	89.4	10.8	30.9	134.8	1047.5
CD	163.3	153.9	14.6	1.9	1.8	1.8	16.3	163.2
Sed	519.7	489.7	46.4	6.1	5.8	5.7	51.9	519.7
Cytoplasmic genetic male sterile lines								
CORG 990052A	1375	1216	159	88.4	11.6	31.2	130	920
CORG 990047A	1488	1313	175	88.2	11.8	29.8	138	1190
CORG 990040A	1386	1246	140	89.9	10.1	28.6	131	870
GT 288A	1456	1808	148	89.8	10.2	27.2	139	1150
Mean	1426.3	1395.8	155.5	89.1	10.9	29.2	134.5	1032.5
CD	177.9	163.3	24.5	2.5	4.2	2.7	17.4	127.3
Sed	566.3	519.7	77.9	7.9	13.3	8.5	55.4	405.1
Comparison of varieties, genetic and cytoplasmic genetic male sterile lines								
CD	57.6	53.49	8.1	0.4	0.4	1.9	2.6	77.7
Sed	140.9	130.6	19.7	1.1	1.1	4.6	6.5	190.1
Significance	** **	**	**	**	NS	**	NS	

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