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Temporal Profiles of Pod Development and Seed Set in Chickpea

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Abstract: The pod ontogeny covers the events from appearance of flower bud, anthesis, setting of pods, development of pod shell, elongation and dry matter accumulation in pod shell, setting of seeds into pod and growth of grain in terms of length, breadth and width are very critical issues and perhaps the pivotal phenomenon in determining the yield. Legume seeds develop within the confines of an ovary-derived pod whose walls provide numerous functions for the seeds. Three *desi* and three *Kabuli* genotypes of chickpea (*C. arietinum* L.) were evaluated for pod and seed development. The tall growing and profuse branching genotype PG-9758-6-2 and *kabuli* genotype Dollar Mexican had relatively low number of pods on secondary branches. The dwarf genotypes Chafa, Vijay and Virat which have high number of nodes per plant, bear profuse pods per plant. The maximum width and maximum volume of the seed was completed within 31 to 32 days from flowering and length and girth were completed within 34 to 35 days from flowering. The maximum dry weight of the seeds occurred within 42 days. Transition from vegetative to reproductive phase occurred by floral bud appearance within 32 days. In next five days the buds opened into flowers and within 10 days from flowering the pod setting occurred. The first pod maturity occurred during 66 days from flowering. The actual average seed development period for six genotypes was 64.16 days. The effective seed development period is approximately 29.83 days. The difference of 34.33 days in actual and effective seed development is lag period. The minimum lag period was in Dollar Mexican (27 days) followed by Virat (29 days) and Chafa (29 days). It was longest in ICCV-2 (53 days). The total chlorophyll content in pod wall was 0.378 whereas the chl-a content was 0.165 mg/g. It is noticed that Vijay was characterized by highest magnitude of total chlorophyll, chl-a and chl-b which was closely followed by Chafa and Virat.

Key words: Ontogeny % Pod growth period % Seed growth % Actual and effective development periods % Lag periods

INTRODUCTION

The legume grain yield is dependent on number of pods per unit area, number of seeds per pod and seed weight and the product of these three determines net yield. Reproductive phase commence with the appearance of buds, opening of flowers, setting of pods, development of pods in terms of length, breadth, girth and volume [1-3]. Seed weight is the most stable character [4]. At present high yielding genotypes of chickpea of both *desi* and *kabuli* are developed and released. However, it is essential to study their growth behavior and differences in the morpho-physiological characters. Maturation of floral parts and seed setting time is the most critical stage in reproductive development, characterized by loss of flower buds or flowers. The pod development period (PDP) is the development of grain and their production in legumes is governed by the length of the reproductive period which in turn depends on the time from anthesis to maturity of individual pods. Pod filling phenophase is another physiological attribute which contribute to high yields. The yield in field crops depends upon deposition of assimilates in the seeds. The quantity of seed yield is a product of number of seeds and their size. This is determined by rate and duration of dry matter accumulation into them. The yield is further defined as a product of average rate of grain production and duration of grain formation [5]. Wien and Ackah [6] have reported that the effective pod growth period is shorter than actual pod growth period and effective pod growth rate is

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different than actual pod growth rate. Chitnis and Jamadagni [7] have estimated the different parameters of seed filling in black gram and have correlated the seed filling parameters with various components of yields in black gram. On this background the studies were conducted to study the growth pattern of pod and seed in three *desi* and three *kabuli* chickpea genotypes and investigated the total, actual and effective pod and seed filling period.

MATERIALS AND METHODS

Three *desi* and three *kabili* chickpea genotypes were evaluated in RBD with three replications during *Rabi* 2006 and 2007 to investigate pod development and seed growth characters at Department of Botany, PVP College, Pravara Loni, Dist. Ahmednagar. The gross and net plot sizes were 4.00 x 3.60 and 3.60 x 3.00 m^2. The ontogenic observations were recorded right from initiation of flower bud to the overall maturity. The chlorophyll content of pod wall was recorded. The pod development/ seed growth studies were undertaken as per the method given by Wien and Ackah [6]. Effective pod and seed development period was calculated by the formula given by Daynard *et al*. [5]. It was expressed as:

$$\text{Effective pod development} = \frac{\text{Final pod dry weight period (days)}}{\text{Pod dry weight increase per day}}$$

$$\text{Effective seed growth} = \frac{\text{Final dry weight of seeds per pod period (days)}}{\text{Seed dry weight increase per day}}$$

Lag period = Actual pod growth period - Effective pod growth period

The total maturity periods of individual pod and maturity period of crops are calculated by using following formula.

Total maturity period (days) = Days to first flower bud + Bud to flower anthesis + Duration for flowering to pod set + Pod set to maturity

Maturity period (days) = First bud appearance (d) + Bud to first flower (d) + First flower to first pod set (d) + first pod set to first maturity (d) + staggered flowering period (d) + period of difference between last flower to first pod (d)

RESULTS AND DISCUSSION

The average duration for the appearance of first flower bud was 32.33 days. This indicates the transition from vegetative to reproductive phase in chickpea occurs in 32 days. The average duration for the appearance of first flower occurred within 36.83 days. Thus from budding only 4-5 days are required for anthesis. The average duration for days to setting of first pod was 47.33 days. Thus, after anthesis approximately 10 more days are required for setting of pods. The average duration of first pod maturity was 66.33 days. The duration from appearance of first pod to first pod maturity was approximately 19 days. There had been high degree of synchrony then the components of maturity period would have remained as below;

Total maturity period = 32 + 5 + 11 + 20 = 68

Thus, if a hypothetical type of high synchrony is taken into consideration then the total maturity period can be finished in 68 days. However, in current investigation the average maturity period was 108 days, which was 40 days longer than the expected total period, which could be due to indeterminate growth habit of chickpea genotypes under study.

The appearance of flower bud continued from 32 days up to 79 days. Thus there is a period of 47 days during which the buds continued to occur in the plant. In the consequence the flowering was also continued for 47 days from the appearance of first flower i.e. up to 83 days from sowing. In fact the day on which the first bud appears was the phase of commencement of reproductive phase.

In chickpea the vegetative growth like emergence and expansion of new branches, formation of new leaves, which are the components of vegetative growth, continue even after flowering phase. Thus the reproductive and vegetative growth occurs simultaneously. Usually at the phase of maturity of first pod, the vegetative growth stops. In current investigation the first pod maturity occurred in 66.33 days but the last flower bud appeared on 79th days. Thus, flowering continued still after phase of first pod maturity. Thus, these appeared an intricate overlapping of occurrence of flower bud even after first pod maturity, which requires critical analysis.

First flower bud appeared within 25 days in Vijay and required 27 to 29 days in ICCV 2, Dollar Mexican and Chafa (Table 1). However, 37 days were required for Virat to first flower bud appearance and 48 days to PG 9758-6-2.

Table 1: Duration for flowering and maturity in chickpea genotypes

Genotype	FFB	FF	FPS	LFB	LF	LPS	FPM	LPM	F	M
Desi										
Chafa	29	34	47	79	84	92	65	105	41	108
Vijay	25	31	44	80	84	91	65	102	42	107
PG 9758-6-2	48	52	60	79	83	91	75	102	63	116
Kabuli										
ICCV 2	27	31	41	79	83	90	61	100	42	104
Virat	37	41	49	79	83	91	70	102	51	110
Dollar Mexican	28	32	43	77	82	89	62	101	46	106
Mean	32.3	36.8	47.3	78.8	83.2	90.7	66.3	102.0	47.5	108.5
SE+	0.74	0.83	0.91	0.82	0.39	0.72	0.68	0.47	1.11	0.57
CD at 5%	2.23	2.49	2.75	NS	1.16	NS	2.06	1.41	3.47	1.72

FFB: Days to first flower bud, FF: Days to first flower, FPS: Days to first pod set, LFB: Days to last flower bud, LF: Days to last flower, LPS: Days to last pod set, FPM: Days to first pod maturity, LPM: Days to last pod maturity, F: Days to 50% flowering, M: Days to maturity

Usually the transition into reproductive phase occurs within 25 to 29 days but Virat and PG 9758-6-2 had exceptionally longer period of vegetative growth. Similarly, first flower appeared within 31 to 34 days in Vijay, ICCV 2, Dollar Mexican and Chafa but in Virat and PG 9758-6-2 requires 41 and 52 days, respectively. The first pod set occurred within 8 days after first floweringi PG 9758-6-2 and Virat, which is an earliest period. In ICCV 2 and Dollar Mexican 10 and 11 days required for first pod set from first flowering. The budding and first flower occurs very early in chafa, however, the period for first flower bud and first pod set were very long i.e. 29 to 47 days. The duration for first pod was very long i.e. 47 days that means after flowering it required 13 days for pod set.

There was no much variation for the duration to appearance of last flower bud (77 to 80 days) in Chafa, PG-9758-6-2 and ICCV-2. Virat had 79 days period for occurrence for last flower bud, however, Dollar Mexican requires only 77 days and Vijay required 80 days for last flower bud. The duration for opening of last flower was 83 days in PG-9758-6-2, ICCV-2 and Virat while 84 days in Vijay and Chafa and 82 days in Dollar Mexican. The duration for first pod set to first pod maturity was 19 days whereas last pod set to last pod maturity was only 12 days. Thus there was a difference of 7 days in pod development period. Shortening of pod development period in late flowering stage was obviously due to enhancing rate of senescence. This 7 days difference in pod maturity increases the complexity of understanding the maturity behavior of chickpea. The duration from first flower to first pod set is 11.50 days whereas the last flower to last pod was 7.5 days. Thus, there was a shortage of 4 days for setting pod in the flower, which are born, in late phase of the crop. There was no considerable variation for days to last pod set (91 to 92 days). Usually the last pod maturity also occurred in 100 to 102 days with an exception of Chafa (105 days) after attaining the physiological maturity within 102 days. Six more days required for over all maturity of the crop. Saxena and Sheldrake [8] indicated that the dry weight increase of pod wall was more than grain during first 15-17 days. Further, till 27th day of anthesis, more than 30 percent of pod dry matter was accumulated in pod wall, subsequently the rate of dry matter accumulation in pod wall was slow down while that of grain increased seven folds. As regards the grain development, it was seen that the grain development, started after 7th day and the rate of grain development was linear between 17 to 37 days of anthesis, after which it was rather slow.

The average number of pods per plant was 8.64 with a maximum of 10.50 in Vijay and minimum of 6.70 in Dollar Mexican (Table 2). The highest number of pods on secondary branches was noticed in Vijay (38.00), which was closely followed by Virat (37.06), Chafa (37.00) and ICCV-2 (34.93). The tall growing and profuse branching genotype PG-9758-6-2 had relatively low number of pods on secondary branches (23.20). Dollar Mexican had lowest number of pods per plant (15.13) on secondary branches. The total number of pods per plant was maximum in Vijay (48.53) closely followed by Virat (46.00), Chafa (44.86) and ICCV-2 (44.20). PG-9758-6-2 had relatively very low pod number (31.86) and Dollar Mexican had minimum pod number per plant (21.86). Achakzai and Bagulzai [9] and Achakzai and Taran [10] also observed significant differences in total number of pods in pea and mash bean respectively. Achakzai et al. [11] noticed variation in yield and yield attributes of soybean in relation to even fertilizer, inoculation and sowing time. Yadav and Bahl [12] reported reduction in internodal length in bushy types specifically under late sown conditions and the multi branching habit of bushy types was adversely affected by late planting [13].

Table 2: Yield components of chickpea genotypes

Genotype	Pods on primary branches/ plant	Pods on secondary branches/ plant	Pods/ plant	Node: pod setting ratio	Biomass/ plant	100 seed weight (g)	Yield/ plant (g)	Yield/ ha (q)	Harvest index
Desi									
Chafa	7.8	37.0	44.9	2.57	12.43	14.93	5.48	20.90	38.66
Vijay	10.5	38.0	48.5	3.74	13.19	17.86	7.02	30.50	43.19
PG 9758-6-2	8.6	23.2	31.9	6.08	21.76	30.73	8.06	26.40	37.51
Kabuli									
ICCV 2	9.2	34.9	44.2	2.82	17.66	23.86	9.13	25.30	40.02
Virat	8.9	37.1	46.0	4.29	23.00	32.00	9.41	28.60	43.10
Dollar Mexican	6.7	15.1	21.9	4.03	23.20	61.06	10.45	21.80	38.90
Mean	8.6	30.9	40.4	3.92	18.54	30.07	8.26	25.58	47.05
SE+	0.88	2.31	2.74	0.31	1.23	1.22	0.63	0.61	3.80
CD at 5%	NS	6.95	8.26	0.93	3.70	3.68	1.88	1.81	NS

The numbers of nodes have direct relation with number of pods per plant; there was an inherent variation for the ability of nodes to bear the pods. This was indicated by the ratio of nodes to number of pods in each genotype. In current investigation, Chafa was found to be more promising type as it had minimum ratio of node to pod (2.57). ICCV-2 (2.82) and Vijay (3.74) were the other two types of this kind. PG-9758-6-2 had high ratio of nodes to pod (6.08) which indicated that there is very good number of nodes per plant but very few of them were fruitful. Dollar Mexican had inherently low number of nodes and also low number of pods and ratio of nodes per pods also high. Virat had high number of nodes but the ratio was 4.29 indicating the scope for increasing the pod set per nodes.

Total biomass is the overall organic frame from which the ultimate yield is derived. Maximum biomass was noticed in Dollar Mexican (23.20), which was closely followed, by Virat (23.00) and PG-9758-6-2 (21.76). ICCV-2, Vijay and Chafa had relatively low magnitude of total biomass (17.66, 13.19 and 12.43 g), respectively. The seed size has a practical commercial value especially in *kabuli* type. Bolder seeded genotypes had preferred premium price. Dollar Mexican had the highest 100-seed weight (61.06 g). Among the remaining genotypes the *kabuli* genotypes Virat had high 100-seed weight (32.00 g). The genotype ICCV-2 had relatively low magnitude of 100 seed weight (23.86 g). In *desi*, bold seeded genotypes are rare. However, PG-9758-6-2 had appreciably high value of 100-seed weight (30.73 g) as compared to Vijay and Chafa (17.86 and 14.93 g), respectively, which had quite small seed. Seed yield per plant was maximum in Dollar Mexican (10.45 g) followed by Virat and ICCV-2 (9.41 and 9.13 g), respectively. Among the three *desi* types PG-9758-6-2 had highest seed yield per plant (8.06 g) which was closely followed by Vijay (7.02 g).

The event of pod development includes appearance of floral bud, opening of flower, setting of the pod, increase in weight of pod, elongation of pod, width and girth wise growth of the pod and attainment of the final volume (Table 3). In current investigation the appearance of first bud in general required 32.33 days and in next five days, the flowering occurred. After flowering, the setting of pod occurred within 10.50 days. The period required for achievement of maximum pod shell weight from the date of flowering was 28.33 days. Thereafter, in next two days the width-wise growth of the pod was completed (30 days from flowering). The elongation was completed in next 3 days after attainment of maximum width i.e. in 33.33 days. The maximum girth and maximum volume were also attained within 35 days from the date of flowering. Thus, the formation of pod shell in length, width and girth-wise as well as completion of volume was achieved within 35 days from the flowering. Thus the site for setting and growth of the seed became ready within 35 days from flowering.

Pod setting occurred within 13 days after flowering in Chafa and Vijay. The length, breadth and girth of the pods were completed within 35 days and maximum volume was attained within 40 days in Vijay. In Chafa maximum dry weight and maximum length were completed within 25 days whereas the completion of width was finished with 20 days. The growth in respect of girth and volume of pod set were completed simultaneously i.e. within 35 days. In PG9758-6-2 and Virat pod set occurred within 8 days from flowering. But the period required for maximum volume was only 30 days. In PG-9758-6-2 a period of 35 days was required for completion of length, width and girth of the pod shell, whereas the volume was completed within 35 days. Among the three *kabuli* types each genotype required 30 days period for maximum dry weight of pod shell from the flowering. Dollar Mexican

Table 3: Components of pod development period in chickpea genotypes

Genotype	Pod set from flowering (d)	Maximum pod shell (dry weight from flowering (g)	Maximum pod length from flowering (cm)	Maximum pod breadth from flowering (cm)	Maximum pod girth from flowering (cm)	Maximum pod size by volume (ml)
Desi						
Chafa	13	25	25	20	35	35
Vijay	13	30	35	35	35	35
PG 9758-6-2	8	25	35	35	35	35
Kabuli						
ICCV 2	10	30	30	30	40	35
Virat	8	30	35	25	30	35
Dollar Mexican	11	30	40	35	35	35
Mean	10.5	28.3	33.3	30.0	35.0	35.0

Table 4: Components of seed development period in chickpea genotypes

Genotype	Seed set from flowering (d)	Maximum seed weight (dry weight from flowering (g)	Maximum seed length from flowering (cm)	Maximum seed breadth from flowering (cm)	Maximum seed girth from flowering (cm)	Maximum seed size by volume (ml)
Desi						
Chafa	18	40	35	25	30	25
Vijay	18	45	35	35	35	35
PG 9758-6-2	13	40	30	30	35	30
Kabuli						
ICCV 2	15	40	35	30	40	30
Virat	13	40	30	30	35	30
Dollar Mexican	17	45	40	35	40	40
Mean	15.7	41.7	34.2	30.8	35.8	31.7

required 35 days for achievement of maximum width, girth and volume, whereas 40 days were required for full elongation of pod. In Virat, completion of full volume and maximum length occurred within 35 days, whereas girth required 30 days and width required 25 days for complete growth. In ICCV-2, 30 days were required for length-wise and width-wise growth and 35 days for maximum volume. Maximum girth of pod was attained within 40 days from flowering. A critical perusal indicated that the deposition of dry matter into pod shell was rather faster than time required for length, width, girth and volume of the pod. This suggests that assimilates are gathered at beginning in the sink and then they are utilized for development of pod in the entire dimension.

The seed setting started from 15 to 16 days from flowering i.e. about 5 days after pod setting (Table 4). The maximum width and maximum volume of the seed was completed within 31 to 32 days from flowering and length and girth were completed within 34 to 35 days from flowering. The maximum dry weight of the seeds occurred within 42 days. Thus, it was clear that dimension of length, width and girth of the seed as well as volume occurred in the beginning and then assimilates is deposited in the seed during next 7 to 10 days.

Chafa, Vijay and Dollar Mexican required 17 to 18 days for setting of the seed from the flowering. This period was minimum PG-9758-6-2 and Virat, i.e. 13 days, whereas, in ICCV-2 it was 15 days. The maximum dry weight of the seed was achieved in 40 days in Chafa, PG-9758-6-2, ICCV-2 and Virat, whereas, Vijay and Dollar Mexican required 45 days for maximum accumulation of dry weight in the seed. The period for maximum seed length was 35 days in Chafa, Vijay and ICCV-2. It was longest in Dollar Mexican (40 days). Whereas, the shortest in PG-9758-6-2 and Virat (30 days). The width of the seeds could be completed within 35 days in Vijay and Dollar Mexican, 30 days in PG-9758-6-2, ICCV-2, ICCV-2 and Virat and 25 days in Chafa. The seed girth became maximum within 35 days in Vijay, PG-9758-6-2 and Virat, however, in ICCV-2 and Dollar Mexican required 40 days. The final volume of the seed was achieved within 30 days in PG-9758-6-2, ICCV-2 and Virat and 35 days in Vijay. It requires the longest period of 40 days in Dollar Mexican and the shortest period in Chafa (25 days). Thus, the whole seed development occurred within a span of 41 to 42 days from the flowering.

Actual pod development period refers to the period from flowering to maturity of the pod, whereas, effective pod development period was equal to final pod dry weight/rate of increase in pod dry weight per day in a linear phase/period. Daynard *et al*. [5] defined effective filling period as final grain yield divided by average rate of grain dry weight accumulation during the linear period of grain formation and hence is a relative measure of the

Table 5: Actual, effective and lag period of components of pod and seed growth in chickpea genotypes

	Pod development (d)			Seed growth (d)		
Genotype	Actual period	Effective period	Lag period	Actual period	Effective period	Lag period
Desi						
Chafa	31	19	12	60	31	29
Vijay	34	21	13	70	34	36
PG 9758-6-2	23	17	6	60	28	32
Kabuli						
ICCV 2	30	22	8	75	22	53
Virat	29	23	6	60	31	29
Dollar Mexican	30	20	10	60	33	27
Mean	29.5	20.3	9.2	64.2	29.8	34.3

Table 6: Chlorophyll ‘a’, ‘b’ and ‘total chlorophyll’ content of leaves and pod wall in six chickpea genotypes

	Chlorophyll content of leaves (mg/g)			Chlorophyll content of pod wall (mg/g)		
Genotype	a	b	Total	a	b	Total
Desi						
Chafa	0.60	0.39	1.13	0.20	0.18	0.45
Vijay	0.82	0.55	1.51	0.22	0.21	0.50
PG 9758-6-2	0.71	0.46	1.29	0.14	0.15	0.33
Kabuli						
ICCV 2	0.81	0.52	1.46	0.13	0.14	0.31
Virat	0.54	0.35	0.96	0.18	0.17	0.40
Dollar Mexican	1.11	0.93	2.28	0.12	0.13	0.28
Mean	0.767	0.533	1.438	0.165	0.163	0.378

length of the grain filling period. The effective filling period duration (EFPD) was unaffected by planting density. The actual average pod development period in chickpea was 29.50 days, whereas average effective pod development period was 20.33 days. Thus, the effective pod development period was shorter than the actual pod development period by about 9.16 days. This difference is referred to as lag period (Table 5).

The actual pod development period was the longest in Vijay (34.00 days), whereas, the effective pod development period was the longest in Virat (23.00 days). The lag period was shortest in PG-9758-6-2 (6 days) and Virat (6 days). The actual pod development period was shortest in PG-9758-6-2 (23 days). The Vijay was characterized by relatively long lag period, longest actual pod development period and short effective pod development period. In contrast Virat showed shortest lag period, longest effective pod development period and short actual pod development period. ICCV-2 also had similar features of pod development period as that of Virat but had two extra days for lag period.

The genotype, ICCV-2 (75 days) had longest actual seed growth period followed by Vijay (70 days). In other genotypes the actual seed growth period was 60 days. The effective seed growth period was longest in Vijay (34 days) followed by Dollar Mexican (33 days), Chafa and Virat had 31 days effective seed growth period. The effective seed growth period was minimum in ICCV2 (22 days). The lag period was maximum in ICCV-2 (53 days) followed by Vijay (36 days) and PG-9758-6-2 (32 days). It was minimum in Dollar Mexican (27 days). Chafa and Virat had equal length of lag period (29 days). Thus, it is clear that the actual seed growth period was longer than the actual pod development period and effective seed growth period is longer than effective pod development period and lag period of seed growth period was longer than lag period of pod growth.

The photosynthesis occurring in pod wall has a great significance at the time of pod filling. Hence, the magnitude of chlorophyll content is an indicative of the ability to support current photosynthates for the development of grains. On an average, the total chlorophyll content in pod wall was 0.378 whereas the chl-a content was 0.165 (Table 6). It is noticed that Vijay was characterized by highest magnitude of total chlorophyll, chl-a and chl-b. Chafa and Virat closely followed it. I n Dollar Mexican the magnitude of chl-a, chl-b and total chlorophyll in pod wall were low in comparison with other genotypes. The genotypes ICCV-2 and PG-97658-6-2 also had relatively low values of chlorophyll content in pod wall.

CONCLUSIONS

Transition from vegetative to reproductive phase occurred by floral bud appearance within 32 days. In next five days the buds opened into flowers and within 10 days from flowering the pod setting occurred. The first pod maturity occurred during 66 days from flowering. The total maturity period was the sum of period for first bud appearance, period for first bud to flowering, flowering to pod set, pod set to first maturity, first maturity to last flower appearance, last flower appearance to last pod set and last pod set to last overall maturity. The pod shell development by weight was completed within 28 days from flowering and in next two days breadth of pod became maximum. Elongation of pod was completed in 3 days after maximum breadth. Maximum girth and volume were achieved after 35 days from flowering. Thus, deposition of assimilates into pod shell was earliest event which occur before complete elongation, widening and achievement of final volume of pods. In brief, pod development is a highly organized process in which development of pod shell, in respect of length, breadth, girth and volume occurs in a precise manner. Seed setting and seed growth starts after setting of pods. Actual development period of pods as well as seeds is different than effective filling period.

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