# AMADEPA
# Association Martiniquaise pour le Développement des Plantes Alimentaires

29ème
CONGRES ANNUEL
ANNUAL MEETING
REUNION ANNUAL

Agriculture Intensive dans les Iles de la Caraibe : enjeux, contraintes et perspectives
Intensive Agriculture in the Caribbean Islands : stakes, constraints and prospects
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# A STUDY OF SOME MORPHOPHYSIOLOGICAL FACTORS AFFECTING YIELD OF PIGEONPEA AND THEIR RELEVANCE TO HIGH INTENSITY PRODUCTION SYSTEMS

FAKIR, M.S.A., McDAVID, C.R. and UMAHARAN , P.

*Department of Plant Science , University of West Indies, St. Augustine , Trinidad , W.I.*

## ABSTRACT

A field study was conducted with 38 $F_6$ lines to investigate abscission patterns and their relationship with yield. The rate of abscission increased with the progression of floral nodal position and time after first flowering implying that genotypes with fewer inflorescence nodes and a shorter, synchronous flowering period might have lower abscission rates and be useful for high intensity production. Abscission rate was found to be negatively correlated with yield suggesting that abscission is an important yield limiting factor and genotypic differences in abscission rate were found which could be utilized in breeding a high yielding cultivar. A green house study using rooting boxes demonstrated variations in both canopy and rooting patterns. The results showed that increased number of branches and low branch angle contributed to an erect and compact canopy in ICPH 8 which had also the highest shoot/root ratio. These results suggest that selection of genotypes similar to ICPH 8 might increase productivity at higher planting density. The physiological implications of some of the variation demonstrated are discussed.

## INTRODUCTION

Pigeonpea (*Cajanus cajan* (L.) Millsp.) is one of the most important grain legume crop in the Caribbean and is consumed generally as cooked green grain peas. Split pigeonpea has been suggested as a substitute to the imported split pea ( *Pisum sativum* ) for the CARICOM countries (Anonymous, 1990), which further heightens its potential as a crop for this region. Despite its potential the yield of pigeonpea remains low, (SHELDRAKE and NARAYANAN, 1979; CHAUHAN, 1990) due to its slow canopy development, inefficient partitioning of dry matter (DM) and high rate of floral abscission, making it as a uncompetitive cash crop. The traditional tall varieties are photoperiod sensitive and flower and produce pods only under short day conditions. The breeding of dwarf, photoperiod insensitive cultivars was a milestone towards the development of a year round crop production system. Although the new cultivars can be grown at any time of the year their yields relative to other legumes still remain low and their successful adoption by farmers requires an increase in their yields under high density production systems.

A wide range of canopy structure with varying number of branches , branch angles and with spreading versus compact form have been identified (REMANANDAN *et al*, 1988). The number and size of branches have been correlated with seed yield (WAKANKAR and YADAV, 1975 ; KUMAR and REDDY, 1982 ; BAINIWAL JATASRA, 1983 ) but information on the relationship between yield and branch angle and the interaction between canopy structure and optimum planting density is limited. Previous studies on the effect of plant densities on yield in pigeonpea have been inconclusive. Some studies showed a positive response to increasing density (WALLIS *et al.*, 1981; CHAUHAN *et al.*, 1987 ) while others have shown little or no response (MOHOYODEEN, 1988; CHAUHAN *et al.*, 1987). The response of cultivars with different canopy structures to high planting density may depend upon the degree of branching, branch angle and spacing. There is also very little information about the extent of variation in rooting pattern between pigeonpea genotypes, which would also be expected to influence the development of yield under conditions of water and nutrient deficiency and high planting densities.

The problem of inefficient partitioning has partly been overcome in the new dwarf varieties (KUMAR and REDDY, 1982 ; BHUTE *et al.*, 1988 ), but even in these cultivars the partitioning of photosynthates during reproductive development to the root system has not been investigated. Recently, a great increase in yield has been achieved in the hybrid variety ICPH 8 (ICRISAT, 1988) although the physiological basis of this increased yield is not clear.

The factor responsible for very high levels of floral abscission in pigeonpea, which have been reported to be as high as 80-90 % (SHELDRAKE and NARAYANAN, 1979; TAYO, 1980; PANDEY and SINGH, 1981; SAXENA *et al.*, 1985 ) are also not clearly understood, and the importance of abscission of reproductive structures as a yield limiting factor remains a subject of discussion.

In the light of the above , this study was undertaken to investigate (1) the pattern of abscission over time in relation to inflorescence position and nodal position in a range of genotypes ; (2) the relationship between floral abscission and yield components in a range of genotypes and (3) the variation in canopy and root system architecture, and its relationship to partitioning of DM, in the high yielding hybrid cultivar and a number of contrasting genotypes. It is hoped that this information would increase our understanding of the physiological basis of yield development in pigeonpea and enable the development of an ideotype for high density production system.

## MATERIALS AND METHODS

To investigate floral abscission patterns and their relationship to yield, 37 dwarf, $F_8$ lines derived from diverse crosses were evaluated in the field, at the University of the West Indies, St. Augustine, during February-March, 1992. The genotypes were planted in single rows with three replications. Three seeds per hole were planted and seedlings thinned to one per hill at 20 days after planting (DAP). A spacing of 60 cm between the rows and 30 cm within the row was used. The plots were well watered, kept weed free and sprayed with insecticide regularly to keep the insect population low particularly at the flowering stage. Three plants per genotype were randomly harvested at maturity for measurement of plant height, number and angle of primary branches, pod and seed yield, and dry mater distribution. Roots were excavated from a soil core of 30 x 15 x 30 cm ( length x width x depth ) and were washed of soil. Samples were oven dried to constant weight and weighed. The rate of floral abscission in one terminal (main stem inflorescence) and three lateral inflorescences (primary branch inflorescences) per plant was determined by counting the number of flowers abscising for about 3 weeks from the beginning of flower opening. Abscission rate was then calculated by dividing the total number of abscised flowers by the total number of flowers produced on the inflorescence and multiplying by 100. Abscission of reproductive structures with their nodal positions were recorded over time. The data were analyzed using a standard software programme (BLP2) obtained from the Caribbean Agric. Res. Institute (CARDI), St. Augustine.

To study canopy architecture, rooting pattern and partitioning of DM into shoot and root, a green house study was conducted during April-July, 1992 using UW 10, ICPL 87, Tobago peas and the high yielding hybrid variety, ICPH 8. Two plants per genotype (one per box) were grown in metal framed wooden boxes (90 x 60 x 15 cm). The boxes were filled with a 2:1 mixture of soil and sand. Compound fertilizer ( N:P:K: in 13:13:21 ) at the rate of 28 g per box (250 kg/ha) was mixed into the soil prior to filling , and the boxes were placed in an open area outside the green house. Five seeds per box were planted and the seedlings thinned to one at 15 DAP. The plants were watered and sprayed with insecticide when required. To expose the roots the boxes were carefully opened and the soil washed away using running water from a garden hose. Plants were harvested at 90-100 DAP for measurement of plant height, leaf area, number of primary and secondary branches, primary branch angle and DM distribution. Branch angle was measured using the formula = $Cos^{-2}(x/y)$ where x and y represent length of main stem and branch. The leaf area was estimated using a regression model Y = 133.03 + 239.27.X established in separate experiment where Y and X represent leaf area ($cm^2$) and leaf blade dry weight (g) respectively.

## RESULTS AND DISCUSSIONS

Abscission and yield in pigeonpea

*(a)Pattern of abscission.* Although abscission rates were determined in all 37 genotypes, data on abscission and yield are presented for only 14 genotypes (Table 1) since these genotypes are representative of the wide range of variation found between the

genotypes studied. The rate of abscission differed between the terminal (TI) and lateral (LI) inflorescences and was always lower in former (Table 1). The percentage abscission increased with the progression of nodal position (Fig.1) and with time after flowering (Fig. 2). There was little difference in the rate of abscission at nodes 1 to 3 , which was between 30-35 % whereas the abscission rate increased markedly after node 5 and varied from 80 to 100 % at nodes 6 to 9 respectively (Fig. 1). It was noted that about 65 % of floral abscission occurred within 15 days of first flowering (DAF). These results suggest that active pod development at nodes 1 to 3 may have contributed to the increased abscission observed in successive nodes and that a genotype with fewer inflorescence nodes and a shorter, synchronous flowering period may be expected to have a lower abscission rate. The high levels of abscission observed in the LI as compared to TI also suggest that a genotype producing a greater proportion of its yield on the terminal inflorescence would have lower levels of abscission. This appears to strengthen the case for high density planting since high density is known to increase the contribution of main the stem.

*(b) Abscission and yield:* There were large differences in abscission and yield between the genotypes (Table 1) and both pod and seed yields were found to be negatively correlated with abscission (Table 2) suggesting that the rate of abscission is an important yield determinant in pigeonpea. Pod number was also significantly correlated with abscission rate and yield (Table 2, 3,). Abscission seems to influence yield by reducing pod number, and the reduction in pod number does not seem to be compensated for by either increased number of seeds/pod or 100-seed weight. Abscission rate varied from 58.5 to 82 % and from 70.5 to 98 % in the TI and LI respectively (Table 1). Some of the values are much lower than reported by previous workers who found on an average only 10 % pod setting (ARIYANAYAGAM, 1975; SHELDRAKE and NARAYANAN, 1979; TAYO, 1980; PANDEY and SINGH, 1981 ). These results indicate that genotypes with lower levels of abscission tended to have higher average yields. The use of genotype(s) with low abscission rate might be beneficial in breeding a genotype favourable for high intensity production systems, but further study of the diverse genotypes across different growing seasons and environments is required.

*(c) Yield and yield components:* The correlations between

yield and morphological variables and yield components are presented in Table 3. Seed yield per plant showed significant positive correlations with plant height and number of branches, primary branch angle, shoot and root weights and total DM. Pod yield and TDM also exhibited a similar relationship with other morphological and yield components (Table 3). The present results are consistent with the reports of previous workers ( WAKANKAR and YADAV, 1975 ; KUMAR and REDDY, 1982 ; BAINIWAL and JATASRA, 1983 ; BHUTE *et al.*, 1988 ). SHARMA *et al.* (1971), however, reported a negative relationship between seed yield and branch angle. Seed yield was positively correlated with TDM suggesting that larger plants would produce higher seed yield. This relationship may however be influenced by the interaction between planting density, branch number and branch angle. The effect of density on performances of genotypes with varying canopy structure needs investigation. The relationship between total root weight and yield has not been investigated previously and the positive correlation between them (Table 3) demonstrates the importance of the root system and emphasizes the need for further research in this direction.

Plant canopy and partitioning of DM

*(a) Canopy structure:* There were large differences in the number of branches and branch angle between cultivars (Table 4). By far the greatest number of primary and secondary branches was produced in ICPH 8 with the lowest number in UW 10. In ICPH 8 and ICPL 87, the primary branches were borne at a narrower angle (18-24°) to the main stem while UW 10 and Tobago Peas had wider angles (26-32°). There were also differences in leaf area development between the dwarf, photoperiod insensitive cultivars (UW 10, ICPL 87) on one hand and the traditional cultivar Tobago Peas, and the hybrid (ICPH 8) on the other (Table 4). UW 10 produced a leaf area (LA) of 0.27 $m^2$ whereas the LA in ICPH 8 and Tobago Peas was 0.42 $m^2$ and 0.48 $m^2$ respectively (Table 4). The increased number of primary and secondary branches with narrower angle in ICPH 8 and ICPL 87 resulted in a more erect and compact canopy structure which might enable increased light penetration into the canopy, thereby reducing mutual shading of lower leaves and increasing light use efficiency. The selection of a genotype

with an erect and compact canopy structure may therefore favour in high biomass production under close spacing.

*(b) Root structure:* The root structure differed between the genotypes and two distinct rooting patterns were observed. The first type shown by UW 10 and Tobago Peas, had a very strong tap root and fewer weak lateral roots while the second category demonstrated by ICPH 8 and ICPL 87, was characterized by a weak tap root and a greater number of strong laterals. The rooting pattern of ICPH 8 and ICPL 87 would be expected to be advantageous under moderately wet conditions whereas the other rooting pattern might be more efficient under dry conditions.

*(c) Dry matter production and its partitioning:* Shoot weight, root and root component weights and total DM production are shown in Table 4. The tap root weight in UW 10 and Tobago Peas was higher, than in ICPL 87 and ICPH 8, reflecting greater partitioning of DM into the tap root development in the former, which might be considered as wasteful and inefficient. The hybrid variety ICPH 8 produced the lowest root weight, second highest TDM, and highest shoot/root ratio, indicating its greater partitioning of DM into shoot development , particularly into the development of leaf area. This might explain the high yield and biomass production in ICPH 8 which has been previously reported (ICRISAT, 1987). Although Tobago Peas produced the highest DM, this might be a reflection of its more perennial nature and it had a much lower shoot/root ratio than ICPH 8 (Table 4). It is suggested that a genotype with greater partitioning of DM into shoot development might be better suited for high biomass production under high planting density, and high biomass is expected to increase yield since yield and biomass were correlated (Table 3).

## SUMMARY AND CONCLUSIONS

The rate of floral abscission increased with the progression of floral nodal position (Fig. 1) and with time (Fig. 2). These results imply that genotypes with fewer inflorescence nodes and a shorter, synchronous flowering period might be better suited for high density planting. There were differences in abscission rates (Table 1) and this variation may be utilized in breeding a high yielding cultivar. Seed yield per plant was found to be negatively correlated with abscission (Table 2), suggesting that abscission is an important yield determinant. Seed yield also showed a positive correlation with TDM (Table 3) which depends upon spacing and canopy structure, particularly the number and angle of branches. There were variations in canopy and rooting patterns between the pigeonpea genotypes (Table 4). The increased number of branches and low branch angle contributed to an erect and compact canopy structure in ICPH 8, which also partitioned relatively more DM into the above ground parts. Two distinct rooting patterns were found. The first type shown by UW10 and Tobago Peas had a very strong tap root and fewer weak lateral roots while the second category demonstrated by ICPH 8 and ICPL 87 was characterized by a weak tap root and a greater number of strong laterals. It is suggested that selection of genotype(s) similar to ICPH 8 would result in improved yield response at higher planting density thus providing an opportunity for increased yield.

## ACKNOWLEDGEMENT

AUTHORS THANK Dr. GREG F. BARCLAY and Dr. GRACE SIRJU-CHARRAN for their corrections and comments during preparation of this article.

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**Table 1. Abscission [1] rates in 14 pigeonpea genotypes**

| | % Abscission | | |
|---|---|---|---|
| Genotype | Terminal inflorescens | Lateral inflorescens | Seed yield/plant (g) |
| A-5-2 | 69.2 | 70.5 | 34.3 |
| A-Bulk-33 | 64.9 | 73.6 | 45.0 |
| A-Bulk-2 | 64.5 | 77.4 | 33.1 |
| A-Bulk-10 | 60.0 | 76.9 | 32.8 |
| A-14-4 | 63.7 | 72.7 | 25.6 |
| A-17B-2 | 63.3 | 75.1 | 33.6 |
| A-1-5 | 64.1 | 74.9 | 27.6 |
| A-7-3 | 64.6 | 77.0 | 26.5 |
| A-2-4 | 58.5 | 77.3 | 25.0 |
| A-6-3 | 59.2 | 73.5 | 28.6 |
| A-3-1 | 74.3 | 98.0 | 13.6 |
| A-AB-2 | 61.5 | 74.8 | 20.0 |
| A-10B-5 | 82.0 | 89.6 | 2.7 |
| UW 10 | 77.3 | 75.6 | 14.4 |
| S.E..+ | 1.4 | 2.1 | 2.9 |

1 Abscission includes buds + flowers + podes together

**Table 2. Correlation coefficients between percent abscission rates and morphological variables in peageonpea genotypes**

| | Independent variable | | | | | | |
|---|---|---|---|---|---|---|---|
| Dependent variable | Root wt (g) | Shoot wt (g) | Total DM (g) | Pod wt | Seed wt (g) | Pod no. (g) | Productive node /infls.(no) |
| Abscission (TI) | - 26 | - 30 | - 30 | - 37 | - 37 | - 43 | - 56 |
| Abscission (LI) | - 41 | - 49 | - 48 | - 52 | - 52 | - 49 | - 86 |

TI : Terminal inflorescence,

LI : Lateral inflorescence

Values $\geq$ 0.33 are significant at P $\leq$ 0.05 probalility