Theor. Appl. Genet. 57, 171-175 (1980)

The Basis for Grain Yield Differences in Mungbean Cultivars and Identifications of Yield Limiting Factors

S.E. Pawar and C.R. Bhatia

Biology and Agriculture Division, Bhabha Atomic Research Centre, Bombay (India)

Summary. Eight mungbean cultivars, selected from a cultivar collection on the basis of their grain yield, were grown in a replicated experiment. Morphological and physiological components contributing to grain yield were analysed. The principal yield limiting factor and the desirable yield component of each cultivar have been identified. The rate of dry matter accumulation was low in all cultivars. It is suggested that for a short duration crop like this, selection for rapid rate of dry matter increase would be advantageous. However, it should also be associated with a high partitioning efficiency (Harvest index). The top yielding cultivar had high biological yield and productive racemes.

Key words: *Vigna radiata* Mungbean – Grain yield – Harvest index – Growth analysis

Abbreviations: BY = biological yield, GY = grain yield, HI = harvest index, DM = dry matter and DW = dry weight, are synonymous, LA = leaf area, GPP = grain protein per cent, GW = grain weight

Introduction

Mungbean (*Vigna radiata* (L.) Wilczek) is widely grown in the Indian sub-continent as a short duration catch crop between two principal crops. The main requirement for such rotations are the short duration cultivars which mature in 60-70 days. The object of the investigations reported here was to identify morphological and physiological factors that limit grain yield in eight mungbean cultivars. Physiological components contributing to grain yield were investigated by simplified growth analysis techniques (Wallace 1975). The factors limiting yield of these cultivars, under our growing conditions, and the desirable character that each cultivar can contribute in a crossing programme have been identified.

Materials and Methods

The original seeds of the cultivars used in this study were obtained from: Prof. S. Ramanujam, Indian Agricultural Research Institute, New Delhi ('Pusa Baisakhi', 'T-1', T-44', 'PS-10', 'ML-5', 'PIMS-1'); Dr. A.S. Tiwari, JNAU, Jabalpur ('4x9') and Dr. Hyo-Guen Park, The Asian Vegetable Research and Development Centre, Shanua, Taiwan ('PHLV-18'). These eight cultivars were selected on the basis of their high grain yield in initial yield evaluation trials with 45 entries at two locations – Trombay and Poona. The present experiment was conducted during 1977-78 in a randomised block design with four replications. Each plot consisted of three 5 m long rows, 30 cm apart, with interhill distances of 5 cm. The exceptions were Cultures 'ML-5' and '4 X 9', which were sampled at weekly intervals and grown in plots of five rows instead of three rows The crops were irrigated as and when required, until they reached near maturity.

Simplified Growth Analysis

Two plants from the side rows of each replication were dug out along with the major roots and nodules. Roots were soaked in water and then washed to remove the adhering soil. Observations on morphological parameters were recorded before separating the different plant parts for drying. Six cultures were sampled at 15 day intervals starting from 30 days after sowing; the two cultivars, 'ML-5' and '4 X 9' were similarly analyzed but at weekly intervals from 21 days after sowing.

Leaf Area

This was determined by drawing outlines of the leaves on graph paper and counting the number of squares covered.

Dry Weight

Plant samples were dried in a circulating air oven at 80°C for 48 h for dry weight estimations.

Pod Dry Weight

Individual flowers were tagged on the day of their opening in order to follow the development of single pods, which were harvested at five day intervals and then dried as mentioned above.

0040-5752/80/0057/0171/$ 1.00

Grain Yield and Yield Components

At harvest, plants in the middle rows were considered for estimating yield and yield components. After leaving a border of 50 cm on either side of the row, plants were pulled out, counted, dried in sun and then weighed for BY before separating the pods which were threshed by hand. BY and GY were adjusted to 40 plants m^2.

Protein Estimations

Representative samples from each replication were analysed by the micro-Kjeldahl method. Seeds were ground in a UDY cyclone mill and 100 mg of flour was digested using Tecator block digestor. Per cent N values were multiplied by 6.25 to obtain GPP.

Statistical Analyses

Differences in yield and yield components were analysed by the 'F' test. For the parameters included in the growth analysis, standard errors were calculated after pooling the values from all four replications. In the figures these are shown as vertical bars only at the peak to avoid crowding.

Other Parameters

Harvest Index was calculated as:

$$\frac{GY}{BY} \times 100$$

The rate of DM accumulation was calculated as plant DM at 45 and 60 days, divided by the number of days. Samples collected on 45 day were closest to flowering and those at 60 day showed peak DM for most cultivars.

Results

Differences among the cultivars in the primary yield components, except seeds per pod and GPP were statistically significant (Table 1). The maximal value for each of the parameters is underlined.

The Pattern of Crop Growth

The general pattern of crop growth is evident from plant DM, stem and leaves DWs and LA for cultivars 'ML-5' and '4 x 9' (Fig. 1). DM accumulation was slow until 35 days and increased rapidly thereafter, reaching a peak at 56 days for cultivar '4 x 9' and at 63 days for 'ML-5'. DW of stem and leaves also followed a similar growth pattern. LA increased rapidly from 27 day onwards. It was maximum at 49-56 days in 'ML-5' and at 56 days in '4 x 9'. A decrease in stem, leaves and plant DWs and LA was observed at the last sampling.

Increase in DW of the pods was maximum between 49 and 63 days in '4 x 9' and between 56 and 70 days in 'ML-5' (Fig. 2a). Single pod growth followed at 5 day intervals after the flower opening revealed that the pod DW reached its maximum in 25 days (Fig. 2b).

Cultivar Differences

The pattern of DM increase for the other six cultivars examined was, in general, similar to that observed for 'ML-5' and '4 x 9' (Fig. 3). All of them show slower rates

Table 1. Variation in grain yield, yield components and grain protein per cent in mungbean cultivars

Cultivar	GY g/m²	BY g/m²	HI	Number of productive racemes	Number of pods/ plant	Pod length cm	Seeds/ pod	100 grain weight g	Grain protein per cent
'ML-5'	<u>85.2</u>	<u>246.2</u>	35.5	<u>4.5</u>	11.1	6.9	11.6	3.9	25.9
'PIMS-1'	72.9	186.7	<u>39.3</u>	4.1	<u>12.0</u>	7.7	11.1	4.2	25.4
'4 x 9'	67.4	194.0	34.9	3.8	8.8	<u>9.3</u>	11.7	5.7	<u>26.3</u>
'T-44'	66.7	168.0	<u>39.3</u>	3.2	9.7	7.7	<u>11.9</u>	3.8	26.0
'Pusa Baisakhi'	65.8	216.0	31.6	4.4	11.0	7.1	11.2	3.8	26.0
'PS-10'	65.0	201.0	32.5	3.1	7.8	7.5	10.9	4.6	25.6
'PHLV-18'	64.2	197.5	32.8	2.9	6.1	8.7	11.7	<u>6.0</u>	25.5
'T-1'	59.3	163.1	36.9	2.7	8.1	7.2	11.3	3.6	25.7
Mean	68.3	196.6	35.4	3.6	9.3	7.8	11.5	4.5	25.8
LSD 5%	10.0	27.5	4.1	0.9	2.5	0.5	NS	0.7	NS
LSD 1%	13.6	37.5	5.6	1.2	3.4	0.6	NS	1.0	NS
C.V. %	2.5	0.1	2.0	4.4	21.5	1.1	1.3	2.7	1.14

NS = Differences not statistically significant

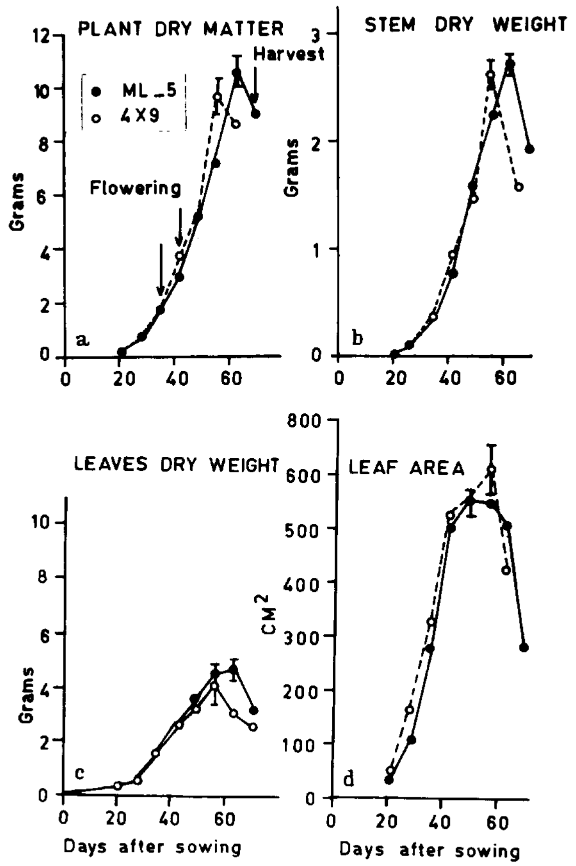

Fig. 1. a plant dry matter, b stem dry weight, c leaves dry weight and d leaf area per plant of mungbean cultivars 'ML-5' (•) and '4 X 9' (o), at different days after sowing

for DM increase during the pre-flowering period and relatively rapid rates after flowering. All cultivars except 'Pusa-Baisakhi' reached their maximal DM at 60 days and thereafter registered a decrease. This loss in DM at the time of harvest was very high (45%) in 'T-1' while for the other cultivars it ranged between 13.9 to 33.1%. Unlike the other cultivars, 'Pusa-Baisakhi' showed increase in DM up to the harvest.

Computed Parameters

Rate of DM increase up to 45 days and at the peak of 60 days after sowing computed from the values in Figures 1a, 3a, b, show marked variation in growth rate (Table 2). Cultivar 'PS-10' had the highest rate up to 45 days, followed by 'PHLV-18' and '4 X 9'. When the growth at the time of attaining maximum DM is considered, 'T-1' followed by '4 X 9' and 'ML-5' had the highest rate of DM accumulation. Cultivar 'Pusa Baisakhi' had the slowest rate both at 45 and 60 days.

Discussion

Grain yield potential of any cultivar depends upon a number of morphological and physiological components contributing to the final yield. In plant breeding programmes, adequate attention is given to the selection for morphological components of yield. Physiological parameters affecting yield are difficult to use as selection criteria in early segregating generations. Simplified growth analysis (Wallace 1975) is a relatively easy method to use in breed-

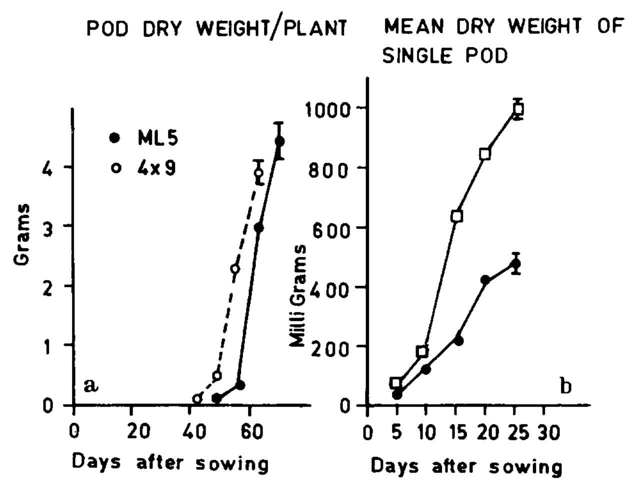

Fig. 2. a dry weight of pods per plant, b mean dry weight of single pod in mungbean cultivars 'ML-5' (•) and '4 X 9' (o), at different days after flowering

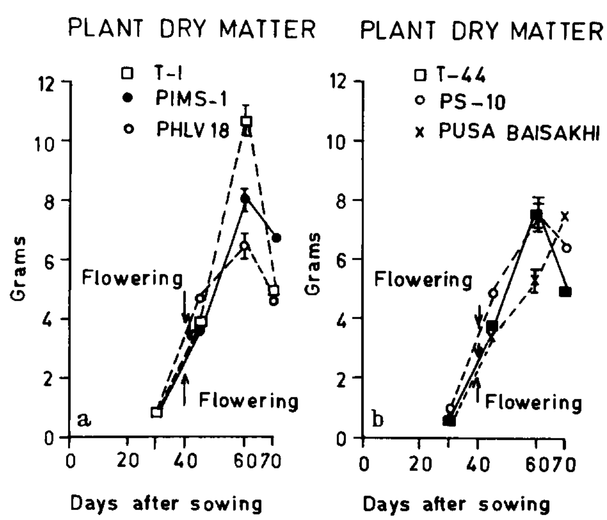

Fig. 3a and b. Plant dry matter in mungbean cultivars at different days after sowing: a 'T-1' (□), 'PIMS-1' (•), 'PHLV-18' (o), b 'T-44' (□) 'PS-10' (o) 'Pusa Baisakhi' (x)

Table 2. Rate of dry matter (DM) accumulation (g per day/per plant)

Cultivar	Rate of DM accumulation	
	Up to 45 days	At the time of attaining maximum DM
'ML-5'	0.081 ± 0.006	0.166 ± 0.007
'PIMS-1'	0.079 ± 0.010	0.136 ± 0.008
'4 x 9'	0.101 ± 0.011	0.168 ± 0.016
'T-44'	0.089 ± 0.011	0.132 ± 0.019
'Pusa Baisakhi'	0.078 ± 0.006	0.110 ± 0.006
'PS-10'	0.109 ± 0.017	0.135 ± 0.028
'PHLV-18'	0.105 ± 0.010	0.114 ± 0.014
'T-1'	0.087 ± 0.008	0.179 ± 0.019

ing programmes in order to evaluate advanced selections and parental stocks to be used in crossing programme. It provides an estimate of two important physiological components of yield (a) the net accumulation of DM (photosynthate) and (b) partitioning of the photosynthates between the economic yield (grain) and the crop residue, at harvest. The partitioning of DM measured as HI has received considerable attention in recent years in cereals (see Donald and Hamblin 1976).

Limiting factor analysis has recently been applied in analysing agricultural production systems to identify the principal factor(s) limiting productivity (Saint and Coward 1977). Essentially it is based on the Blackman's principle of limiting factors which states that the rate of a process controlled by several factors is only as rapid as the slowest factor permits. The principal limiting factor identified can then be rectified and thus, the analysis helps in arriving at the priorities to be considered in the advancement of agricultural production. Since grain yield is the end product of several morphological and physiological characters, limiting factor analysis could be useful in plant breeding programmes in identifying the principal limiting component of yield. This would be especially useful in those crops where extensive breeding efforts have not been made as yet, as is the case with the tropical grain legumes.

The primary components of grain yield in mungbean are: the number of pods/m^2 × number of grains per pod × 100 GW. The number of pods/m^2 depends upon the number of plants/m^2 and the number of productive racemes. The number of productive racemes, pods and pod length can be easily selected in segregating populations.

Studies on physiological basis of yield in mungbean have been initiated at the Asian Vegetable Research and Development Centre. Their recent report (Kuo et al. 1978) indicate that the principal factors limiting yield are insufficient DM production before anthesis and also during the period of pod development. It is also suggested that increasing the efficiency of mobilization of current photosynthates to seed, during pod development is desired. The present results also indicate that DM is low at the first flowering in the cultivars sampled. Chandra et al. (1977) have reported wide variability for relative growth rate, net assimilation rate and leaf area ratio among 25 mungbean cultivars. Two cultivars ('T-1' and 'Pusa-Baisakhi') in our studies were also included in their experiments. They have reported negative association of yield and net assimilation rate at pre-flowering stage and conclude that early vigour did not give any advantage to the cultivars included in their experiment. Our data and that of Kuo et al. (1978) suggests that the rate of DM accumulation in mungbeans is low and for a short duration crop selection for rapid rates of DM growth would be advan-

Table 3. Principal yield limiting factor and desirable yield component which each cultivar can contribute as a parent in crossing programme

Cultivar	Principal yield limiting factor	Desirable yield components
'ML-5'	Low 100 GW	High GY, BY, plant DM and number of productive racemes
'PIMS-1'	Low rate of DM accumulation	High HI and number of pods
'4 x 9'	Low HI	Pod length and high 100 GW
'T-44'	Low rate of DM accumulation	–
'Pusa Baisakhi'	Low rate of DM accumulation	Continues to show increase in DM till harvest
'PS-10'	Low HI	–
'PHLV-18'	Low number of pods	High 100 GW
'T-1'	Low number of productive racemes and 100 GW	High rate of DM accumulation

tageous provided it is also associated with a high partitioning efficiency (HI).

The variation in HI as measured at the time of harvest does not seem to give a true picture of the partitioning in this crop as a considerable decrease in DM was observed in all cultivars except 'Pusa Baisakhi'. Though the DM lost as fallen leaves was not measured, it may account for a major part of the loss in DM prior to harvest.

Experiments conducted in our laboratory indicate that rapid senescence of leaves in mungbean could be caused by remobilization of nitrogen from leaves to developing grains as reported for soybean (Sinclair and de Wit 1976). Variation in the senescence and fall of leaves may therefore be related to differences in their nitrogen metabolism and N demand of developing seeds. The data permits us to identify the factor(s) mainly responsible for limiting GY and some of the desirable attributes of each cultivar. These are summarised in Table 3. Cultivar 'ML-5', which gives the highest yield, has low 100 GW. At the same time it shows high BY and number of productive racemes. Crossing programmes and induced mutation experiments are in progress to improve upon the 100 GW in this cultivar.

Literature

Chandra, S.; Yadav, A.K.; Sagar Prem, (1977): Growth attributes in mungbean. Indian J. Genet. Plant Breed. **37**, 415-419

Donald, C.M.; Hamblin, J. (1976): The biological yield and harvest index of cereals as agronomic and plant breeding criteria. Adv. Agron. **28**, 361-404

Kuo, C.J.; Wang, L.J.; Cheng, A.C.; Chou, M.H. (1978): Physiological basis for mungbean yield improvement. In: Proc. First Intern. Mungbean Symp. (ed.: Cowell, R.) pp. 205-209 Taiwan: AVRDC

Saint William, S.; Coward Jr., E.W. (1977): Agriculture and behavioral science: emerging orientations. Science **197**, 733-737

Sinclair, T.R.; de Wit, C.T. (1976): Analysis of carbon and nitrogen limitations to soybean yield. Agron. J. **68**, 319-324

Wallace, D.H. (1975): Simplified growth analysis procedures. In: Report of the TAC Working Group on the Biology of Yield of Grain Legumes, Annex V. TAC Secretariat, pp. 1-4. Rome: FAO

Received November 2, 1979
Communicated by B.R. Murty

Dr. S.E. Pawar, Dr. C.R. Bhatia
Biology and Agriculture Division
Bhabha Atomic Research Centre
Bombay 400 085 (India)