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Growth Stage Identification in Mungbean (*Vigna radiata* (L.) Wilczek)

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ABSTRACT

Growth stage descriptions were developed for mungbean (*Vigna radiata* (L.) Wilczek) based on measurements and visual observations of mungbean plants grown in four successive experiments conducted from May 1986 to November 1978 at Chainat Field Crop Research Center, Department of Agriculture and Department of Agronomy, Kasetsart University.

It is proposed that the growth stages of mungbean be defined in terms of vegetative (V) and reproductive (R) stages. The V stages are numbered $V_{(o)}$ - $V_{(n)}$, and are determined by counting the number of developed nodes on the main stem, beginning with the cotyledonary node as zero. The last node counted must have its trifoliate leaf sufficiently expanded so that leaflets are unfolded and flat in appearance. The R-stages proposed are R_1 (first open flower), R_2 (first pod), R_3 (start of seed growth), R_4 (full seed), R_5(first mature pod), R_6 (1st harvest) and R^7 (2nd harvest). The V and R stages can be measured separately and concurrently and apply to a population, or to single plants.

When mungbean cultivars, Kamphaeng Saen 1 (KPS-1), Kamphaeng Saen 2 (KPS-2), Uthong 1 and Chainat 60 were grown in a randomized complete block design at Chainat Field Crop Research Center (Chainat FCRC) in May and August 1986. Also at Kasetsart University (KU) cultivars KPS-1, KPS-2, and U-thong 1 were grown in May and August 1987. It was found that, cultivars KPS-1, KPS-2 and U-thong 1 grown at KU matured in 86 and 78 days at May and August planting. At Chainat, cultivars KPS-1, KPS-2 and U-thong 1 matured in 58 days regardless of planting dates, while Chainat 60 matured in 51 and 52 days for May and August planting respectively. At all locations tested, all mungbean cultivars at least completed their vegetative growth up to V_6 before shifting to R_1. In many cases, the plants extended their vegetative growth up to V_7 before flowering depending on genotypes, planting dates and locations. To complete its life cycle, the mungbean plants consequently exhibited R_1 up to R_7 growth stages.

The propose growth stage description of mungbean should be potentially useful and facilitate a common understanding among researchers and extension personnels and should provide a more precise basis for scheduling cultural practices for mungbean.

Key words : growth stage, mungbean, growth description, V-R growth stages

INTRODUCTION

It is important for scientists to be able to identify the growth stages of the crop that they are working with, using terminology which can be commonly understood. Therefore, scientists have proposed methods for identifying the growth stages of crops such as maize (Hanway, 1963), sorghum (Vanderlip and Reeves, 1972), wheat (Waldren and Flowerdays, 1979), and cotton (Elsner, Smith and Owen, 1979). Among the grain legume crops, growth stage identification was firstly porposed for soybean by Hanway and Thomson (1971). Later Fehr *et al.*, (1971) and Fehr and Caviness (1977) introduced the system of soybean growth stage identification which is currently used internationally. Subsequently, Boote (1982) proposed analogous growth stage development descriptions for Spanish and Virginia type groundnut, based on visually observable vegetative (V) and reproductive (R) events.

Mungbean (*Vigna radiata* (L.) Wilczek) is one of the important economic grain legume crops of Thailand. While research in mungbean has been conducted extensively in various institutes throughout the country, we lack standard methods of identifying the growth stages of this particular crop when data on growth, pest and disease

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infestation are being collected. The value of counting days after emergence (DAE) or days after planting (DAP), as have been widely used previously is limited because different genotypes of mungbean respond quite differently to changes in environment (Pookpakdi *et al.*, 1988).

The objective of this study was, thus, to record the growth and morphology of mungbean in details, so that an objective on description of the stages of development could be achieved. The use of V and R stages was patterned after those developed for soybean (Fehr and Caviness, 1977; Fehr *et al.*, 1971) and groundnut (Boote, 1982), because those systems have been successful and a similar approach would allow a given V or R stage to mean the same for these three grain legume crops.

Definitions of Growth Stages

1. Node Identification

We propose that the determination of the vegetative growth stage (and part of the reproductive growth stage of mungbean) be based on the number of developed nodes on the main stem. Nodes, rather than leaves, are better used for stage determination, because they are permanent, whereas leaves may be lost. For example, when a mungbean plant drops its leaves, the nodes can be easily identified by the petiole scars which are permanently shown on the main stem. We suggest that the node at which the cotyledons are attached (the cotyledonary node) be counted as node "zero" and the node at which the two unifoliolate leaves are attached to the stem be counted as node "one". In mungbean, trifoliate leaves are attached at all nodes above the unifoliolate node, and it is proposed that those in turn be numbered node 2 to node "n". The trifoliolate leaves comprised of three small leaflets forming a compound leaf and can be differentiated from the unifoliolate leaves which are simple. We suggest that a node be counted as being developed when its trifoliolate leaf has developed to the stage that the leaflets are unfolded and flat.

2. Vegetative growth stages

The vegetative growth stage (V-stage) was counted from the time at which mungbean emerged until the point in which first flower at the main stem opened. Although, vegetative growth of grain legume crop such as mungbean can be extended after first flowering due to its indeterminate habit in nature. However, for the purpose of growth stage identification, the V-stage is regarded from emergence up to the point at which the first flower open. The "VE" or emergence is defined as cotyledons emerge near the soil surface with some part of the plant visible in half of the seedlings (Table 1). "VE" in grain legumes is primarily dependent of soil temperature and soil structure. "VC" or cotyledon stage is classified as the stage in which the cotyledon are fully expanded and unifoliolate leaves above unroll in such a way that the leaf edge is not touching each other. From VC, the subsequent V-stage is determined by the number of node at which the unifoliolate or trifoliolate leaves attached have developed sufficiently, starting from V_1 (node "one" in which two unifoliolate leaves attached) V_2 (node "two" in which first trifoliolate leaf attached) V_3, V_4, V_5 up to V_n. n is used as the node number in which the fully developed leaf is found attached before the plant show any open flower on the main stem (Table 1).

3. Reproductive growth stages :

The reproductive growth stage (R-stage) was counted from the time in which mungbean showed the first open flower on the main stem, through the period of pod and seed development, seed filling period and maturity. Growth stage of mungbean during reproductive phase was designated by the letter R followed by the number 1, 2, 3, to 7, respectively. The detail of the R-stages of mungbean are shown in Table 2.

Reproductive stage R_1, (beginning bloom), is defined as the stage when one open flower is found on the main stem of the plant. In mungbean, number of days to R_1 is primarily influenced by photoperiod and temperature. The stage R_2 (beginning pod) is defined as stage at which one pod of 1.0 cm. long is found between node 4-6 of the main stem. The main reason that the node number 4-6 were chosen was that the axillary buds located at the leaf axis of node "zero" to node "three" do not develop into inflorescence. First inflorescences and pods of the main stem normally developed from axillary buds in node "four" to node "six" but the frequency of bud in node "five" to develop into the first inflorescence of the main stem is greatest. Axillary buds in node "zero" to "three", if not dormant, will develop into branch. Therefore, the time at which one pod of 1.0 cm. long is found in between node 4 to 6 is identified as R_2 or beginning pod stage.

R_3 is defined when at least one pod of 5.0 cm. is found on any of the three upper nodes of the main stem. At this stage, small visible size of seeds can be found from the pods which earlier developed in the lower nodes. This stage is considered as "beginning seed". R_4 is defined when at least one pod on any of the three upper nodes of the main stem showed the concaved figure in between seed cavities of pod. The stage can be considered as "full seed" or "mid-pod fill". At this stage, the seed fill period has not reached the maximum phase. However, approximately 7-10 days, the first few pods which developed earlier will begin to mature.

4. Maturity

Mungbean pods do not mature at the same time, pod maturation of local and unimproved varieties took more days between the first and the last mature pod, causing high labour cost of harvesting. R_5 (first pod ripening or beginning maturity) is defined as the stage in which one pod on the main stem turns brown, dark brown or black in colour. After R_5, all the pods begin to mature simultaneously until reaching R_6. R_6 (1st harvesting) is defined as the stage in which 50% of pods on the plant mature and ready for harvesting. After harvesting mature pods at R_6, when the rest of pods on the plant mature approximately 90%, the stage R_7 (2nd

Table 1 Vegetative growth stage (V-stage) in mungbean.

Growth stage	Abbreviated stage title	Description
VE	Emergence	Cotyledons near the soil sruface with the seeding showing some part of the plant from the soil surface.
VC	Cotyledon	Cotyledons separate from each other on the upper surface. Unifoliolate leaves start unroll so that the edge of the leaves are not touching each other.
V_1	First node	Unifoliolate leaves attached to the first node are fully expanding and flat while the 1 st trifoliolate leaf attached to the upper node starts unroll.
V_2	Second node	1st trifoliolate leaf attached to the second node is fully expanding and flat while the 2 nd trifoliolate leaf on the upper node starts unroll.
V_3	Third node	2nd trifoliolate leaf attached to the third node is fully expanding and flat while the 3rd trifoliolate leaf on the upper node strats unroll.
V_4	Fourth node	3rd trifoliolate leaf attached to the fourth node is fully expanding and flat while the 4 th trifoliolate leaf on the upper node starts unroll.
$V_{(n)}$	N-node	a node is counted when its trifoliolate leaf is unfolded and its leaflets are flat.

Table 2 Reproductive growth stage (R-stage) in mungbean.

Growth stage	Abbreviated stage title	Description
R_1	beginning bloom	one open flower at any node on the main stem.
R_2	beginning pod	one pod of 1.0 cm. in length is found in between node "4" to node "6" of the main stem.
R_3	beginning seed	one pod of 5.0 cm. in length is found on any of the top three nodes on the main stem.
R_4	full seed	one pod on any of the top three nodes has constriction between seed.
R_5	beginning maturity	on pod on the main stem turns to brown, dark brown or black in colour.
R_6	first harvest	fifty percent of pods on the plant mature.
R_7	second harvest	after harvested the riped pods at R_6, when the rest of the pods on the plant mature, then, R_7 is reached.

harvest) is reached.

Although pod maturation of the improved mungbean varieties such as U-thong 1, Kamphaeng Saen 1, Kamphaeng Saen2, Chainat 60 are not fully syncronized, however, farmers pick the pods of those mungbean varieties twice due to high amount of pods mature at R_6 and R_7. In an unimproved varieties, pod maturity are generally gradual making the period between R_5 to R_6 or R_6 to R_7 much longer. However, if one followed the definition of R_5, R_6 and R_7 growth stage accurately, the stage R_6 and R_7 can also be identified.

Application of the Proposed Growth Stages to Thai Mungbeans

The growth stages description of mungbean proposed as shown in Table 1 and 2, and also the discussion in the previous section were developed based on visually observation of several Thai mungbean genotypes grown in two consecutive seasons at Chainat Field Crop Research Center (Chainat FCRC) Department of Agriculture and the Depart ment of Agronomy, Kasetsart University (KU) in Thailand. In order to derive at the different growth stage descriptions, several morphological and phenological characters had been repeatedly observed and recorded. In this section, the authors attempted to report the test of mungbean growth stage system on a range of Thai mungbean genotypes grown in different sites and seasons.

MATERIALS AND METHODS

This paper reports collaborative research conducted by Chainat FCRC and KU, at Chainat FCRC, four mungbean cultivars, Kamphaeng Saen 1 (KPS-1), Kamphaeng Saen 2 (KPS-2), Chainat 60 and U-thong 1, were sown in the early rainy season (May, 1986) and late rainy season (September, 1986).

At KU, three cultivars of mungbean were sown in two consecutive experiments conducted in March, 1988 at Bangkhen campus in Bangkok; and in August, 1988 at the National Corn and Sorghum Research Center, Nakhon Ratchasima Province.

Procedures for crop establishment and management were similar throughout the four experiments conducted at both locations. Briefly, the mungbeans were sown in randomized complete block design experiments with four replications. The plant spacing used was 50 cm. between rows and 20 cm. between hills within row. Before sowing, seeds were dressed with fungicide "Dithane M-45", three to five seeds were planted in each hill and seedlings were thinned to one plant per hill after emergence. Weeding, irrigation and spraying of insecticide were provided as necessary to ensure good plant growth.

Basically, phenology data such as days after planting (DAP), days after emergence (DAE), days to first flowering (50% of plant in the plot produced at least one flower) and days to maturity were taken. Other morphological data such as number of nodes, branches, leaves, pods, and plant height at each of the growth stages were recorded.

RESULTS AND DISCUSSION

Number of days to reach different growth stages

Table 3 showed the number of days after planting which take to reach different growth stages of different mungbean genotypes when grown in March 1988 at Bangkhen campus and August 1988 at National Corn and Sorghum Research Center at Nakhon Ratchasima province.

Generally, all mungbean genotypes matured at 86 and 78 DAP when planted in March and August 1988. An increase in photoperiod in March tended to lengthen maturity of mungbean genotypes as it was previously demonstrated by Pookpakdi *et al.*, (1988).

When grown at Bangkhen campus in March 1988, there was a similarity between KPS-1 and 2 in number of days required to reach different growth stages. (Table 3) The vegetative stages were extended up to V_6 and the plant produced the first flower at R_1 stages three days afterward. Comparing KPS-1, KPS-2 and U-thong 1, it was shown that the vegetative phase of U-thong 1 extended up to V_7 at 29 DAP before shifting to reproductive R_1 stage. U-thong 1 took slightly longer time to reach the different R stages when compared to KPS-1 and 2. However, the cultivar U-thong 1 took the same length of time to reach R_7 or full maturity as similar to KPS-1 and 2.

When grown at the National Corn and Sorghum Research Center at Nakhon Ratchasima, all three mungbean genotypes took slightly different in number of days to reach different growth stages. KPS-1 and U-thong 1 extended their vegetative phase up to V_7 in 35 and 37 days respectively before shifting to R_1. During the reproductive phase, U-thong 1 took slightly longer time to reach the same R stages. KPS-2 took 31 DAP to reach V_6 and shifted to R_1 3 days afterward. Similarly, all the three mungbean genotypes tested reached full maturity (R_7) during the same times.

Table 4 showed the days after planting of mungbean cultivars KPS-1, KPS-2, Chainat 60 and U-thong 1 at

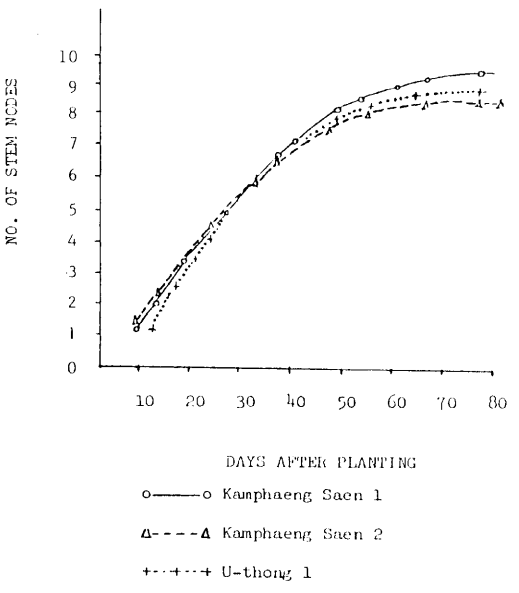

Figure 1 **Development of nodes on main stem of three mungbean varieties grown in the wet season of 1988 at National Corn and Sorghum Research Center, Thailand.**

different growth stages in the experiments conducted at Chainat FCRC in May and August 1986 respectively. Basically, it was found that cultivars KPS-1, KPS-2 and U-thong 1 reached full maturity (R_7) in 58 DAP while cultivars Chainat 60 showed its early maturing characteristic and took 51 and 52 days to reach R_7 in May and August planting. Crops grown at Chainat matured earlier than those grown at the National Corn and Sorghum Research Center due to

Table 3 **Days after planting of mungbean varieties Kamphaeng Saen 1 (KPS-1), Kamphaeng Saen 2 (KPS-2) and U-thong 1 at different growth stages in the experiments conducted at Bangkhen Campus and National Corn and Sorghum Research Center in March and August 1988 respectively.**

Growth stage	KPS-1		KPS-2		U-thong 1	
	March	August	March	August	March	August
VE	2	3	2	3	2	3
VC	3	4	7	4	3	4
V1	9	11	9	11	9	11
V2	13	15	13	15	13	15
V3	16	19	16	19	16	19
V4	19	22	19	22	19	22
V5	22	27	22	27	22	27
V6	26	31	26	31	26	32
V7	-	35	-	-	29	37
R1	29	37	29	33	31	39
R2	30	38	30	34	32	40
R3	34	42	34	39	35	44
R4	37	49	37	47	39	50
R5	41	58	41	57	45	59
R6	56	71	56	71	56	71
R7	86	78	86	78	86	78

Table 4 **Days after planting of mungbean cultivars KPS-1, KPS-2, Chinat 60 and U-thong 1 at different growth stages in the experiments conducted at Chinat in May and August 1986 respectively.**

Growth stage	KPS-1		KPS-2		Chainat 60		U-thong 1	
	May	August	May	August	May	August	May	August
VE	2	3	2	3	2	3	2	3
VC	3	4	3	4	3	4	3	4
V1	6	10	5	10	6	10	6	10
V2	14	18	14	18	14	18	14	18
V3	19	21	18	21	18	21	19	22
V4	21	24	21	24	20	24	21	24
V5	23	26	23	28	24	26	25	31
V6	28	31	27	31	28	21	29	33
V7	30	33	30	33	-	-	31	-
R1	33	35	33	35	29	33	33	37
R2	36	37	35	37	33	35	36	38
R3	39	38	39	38	36	37	39	40
R4	42	40	42	40	41	39	42	44
R5	45	45	46	45	43	44	45	46
R6	51	52	52	52	48	47	54	52
R7	58	58	58	58	51	52	58	58

drought and erratic rainfall at Chainat in 1986. Unlike at KU, cultivars KPS-1 and KPS-2 extended their vegetative phase up to V_7 before shifting to R_1 in May and August planting. When planted in May, cultivar U-thong 1 reached V_7 in 31 DAP while those grown in August reached V_6 at 33 DAP and shifted to R_1 in 37 DAP. At both planting dates, cultivar Chainat 60 extended its vegetative growth up to V_6 and reached R_1 in 29 and 33 DAP for May and August planting respectively. Results of these experiments suggested that mungbean may extended their vegetative growth phase up to V_n depending on the environmental factors which control flowering. However, the plants has to consequently exhibit their reproductive R_1 up to R_7 in order to complete their life cycles.

Node development of the main stem

Figure 1 showed the number of nodes developed on the main stem of mungbean cultivars U-thong 1, KPS-1, and KPS-2 in the experiment conducted at KU in August 1987. From the figure, it can be seen that the three genotypes developed their first nodes at 11 DAP. After R_1, the number of nodes continued to increase showing the typical indeterminate habit of mungbean. Number of node stop increasing at approximately 45-50 DAP when the plant reached R_5 (beginning maturity). This is an indication that indeterminate habit of mungbean is much stronger than those found in soybean plant.

CONCLUSION

Vegetative and reproductive growth stages were proposed and developed for mungbean with the aim of assisting scientists, researchers and extension workers to describe the life cycle of mungbean or green gram. It is hoped that this growth stages should be beneficial for users beacause they are based on discrete, objective and visually identifiable events in mungbean's life cycle. Furthermore, the system of describing the entire life cycle of vegetative and reproductive growth in terms of the whole plant as used similarly in soybean (Fehr and Caviness, 1977), groundnut (Boote, 1982) and in mungbean would provide a more precise basis for scheduling cultural practices for mungbean crop.

As it has been well documented that tht environmental factors particularly the climatic factors such as solar radiation, temperature and precipitation play an important role in governing phenology of food legumes such as soybean and mungbean. This paper also demonstrated how mungbean advances its growth throughout different growth stages in its life cycle. However, the extend of vegetative phase which plant develops, the shift from V to R stages and the length of time the plant reaches each of the different growth stages would depend upon cultivars and environments.

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