

Regional and Seasonal Effects on Phenology of Mungbean (*Vigna radiata* (L.) Wilczek) and Black Gram (*Vigna radiata* (L.) Hepper) in Thailand

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ABSTRACT

Knowledge of how the environment affects the development and growth of a crop, and how different genotypes respond to particular environmental factors, is a prerequisite to directed plant improvement. This paper is a progress report on a collaborative study being conducted within Thailand to examine the regional and seasonal components of environmental effects on growth and development of fourteen mungbean (*Vigna radiata* (L.) Wilczek) and six black gram (*Vigna radiata* (L.) Hepper) genotypes. In the study, sowings of all genotypes were made at monthly intervals in five locations distributed throughout Thailand : Phitsanulok, Khon Kaen, Chainat, Kamphaengsean and Hat Yai. Plantings commenced in mid-1986 and ended in mid-1987. Phenological data from the first six months of the study are presented and discussed in terms of two key climatic factors affecting plant growth and development, daylength and temperature. Averaged over genotypes, effects of location and sowing date were large. In general, flowering occurred earlier at more southern locations and, as sowing was delayed from May to September. However there were also significant genotype interactions with planting locations and sowing dates. In general, the phenological responses observed within both mungbean and black gram were consistent with either daylength insensitivity or quantitative short-day photoperiodic response.

INTRODUCTION

Mungbean (*Vigna radiata* (L.) Wilczek) and its close relative, black gram (*V. mungo* (L.) Hepper), are key economic crops in Thailand and other south-east Asian countries. They are nutritionally rich but low-yielding, warm-season pulses (MacKenzie *et al.*, 1975). Both crops are predominantly of tropical distribution although Poehlman *et al.* (1976) reported that mungbean

can be grown successfully to latitudes as high as 40° where mean daily temperatures exceed 20°C. Mungbean and black gram provide a valuable supplemental protein source in diets based on rice (Tsou and Hsu, 1978) and opportunities exist for expanding production, particularly if yield levels can be improved (Imrie *et al.*, 1981 b).

Mungbean, and to a lesser extent black gram, have been widely used in sequential, rice-

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based cropping systems in Thailand. In Payao province of Northern Thailand, mungbean is grown in the paddy fields in late April or early May, before rice. These plantings take advantage of the early rains, and provides farmers with an income supplement in a short period (ca. 70 days) (Chandrapanya *et al.*, 1985). In the Central Plains region, mungbean is grown after rice in a sequential, three-crop system (Pookpakdi, 1979). Seed is broadcast into the rice stubble immediately after the rice is harvested.

Because mungbean is extensively used in various cropping systems throughout Thailand, the seasons and locations when and where the crops are grown represent a wide range of environments. Consequently, environmental effects on phenology, growth and yield are large. Different genotypes react differently to the various environments. The aim of plant improvement is to develop cultivars which are better-adapted, given the prevailing conditions at a location; also to devise agronomic strategies which minimise the particular constraints imposed by the environment at a given location.

The objective of the experiments described in this paper was to generate information on growth and development of mungbean and black gram when grown at different locations and in different seasons in Thailand. In order to examine the implications of genotype $\times$ environment interactions for improvement of these crops in Thailand, the paper concentrates on the effects of location and growing season on the phenology of the two crops.

Phenology is a key element in the adaptation of any crop to its environment. Crop duration must necessarily be matched with the duration of conditions favourable to growth, while the durations of vegetative and reproductive growth need to be balanced. In this context, time of flowering is particularly important. If the crop flowers too early, the vegetative phase is reduced so that plants may not have sufficient time to produce vegetative organs and establish

photosynthetic capacity to sustain pod and seed growth. In contrast, a very long vegetative phase frequently leads to excessive vegetative growth, lodging and a high level of disease, resulting in a lower harvest index and yield.

Research on a range of food legumes has shown that, among climatic factors, day-length and temperature are particularly important and can cause substantial variation in flowering between locations and seasons (Lawn and Williams, 1987). Most soybean genotypes for example, are quantitative short-day plants, and various phenological sequences such as time to flowering and to maturity are greatly affected by daylength (Garner and Allard, 1930; van Shaik and Probst, 1958; Hartwig, 1970). Photoperiodic responses are further modulated by temperature (Roberts and Summerfield, 1987). Likewise, most mungbean and black gram genotypes are quantitative short-day plants, although daylength insensitivity is believed to exist (MacKenzie *et al.*, 1975; Lawn, 1979). Eagleton and Sandover (1987) reported substantial variation among mungbean genotypes in response to sowing date in a low-latitude environment, primarily as a consequence of variation in photothermal regime. Some flowered within 40 days regardless of season, while others flowers as late as 70 days when sown in summer.

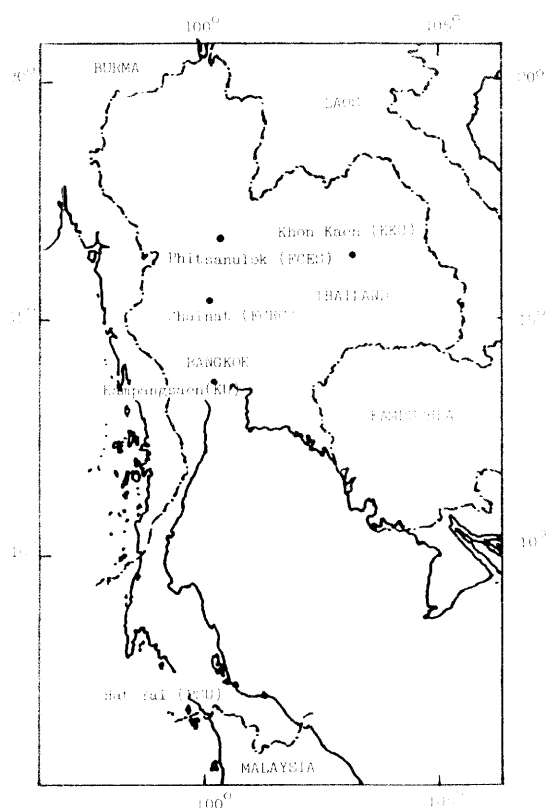
Daylength is entirely predictable, varying in a regular manner with latitude and season (Figure 2). Temperature is also reasonably predictable but to a lesser degree; there are reasonably consistent differences between seasons of the year at a location, and between locations. It is therefore possible to predict fairly reliably, a major part of regional and seasonal variation in climate. These predictions when combined with an understanding of how different genotypes respond to photothermal regime (Roberts and Summerfield, 1987) can be used to predict how various genotypes will perform in different seasons and locations. A second key element of study is to attempt to relate variations in plant

performance, particularly phenology, to variations in climatic factors.

MATERIALS AND METHODS

Experimental sites :

Experiments were conducted in five locations — Phitsanulok Field Crops Experiment Station, Chainat Field Crops Research Centre, Kamphaengsaen Campus of Kasetsart University, Khon Kaen University in Khon Kaen, and Prince of Songkla University in Hat Yai (Figure 1).



KU : Kasetsart University
 KKU : Khon Kaen University
 PSU : Prince of Songkla
 PCES : Field Crop Experiment Station
 FCRC : Field Crop Research Center

Figure 1 Location of experimental sites in Thailand used to examine regional and seasonal effects on phenology of mungbean and black gram

Sowing dates :

In order to sample the seasonal variation in photothermal regime at each site, 12 sowings at regular monthly intervals were made, one at the same time each month, commencing in May or June 1986, and ending mid-1987. While it was recognised that farmers would not ordinarily wish to sow at many of these dates, the year-round sowings enabled a wider range of environmental conditions to be sampled, and therefore crop response to these conditions to be fully described.

Genotypes :

Fourteen mungbean and six black gram genotypes were chosen for the study (Table 1). In order to establish a comprehensive overview of response types within the two species, genotypes were chosen to provide a range of phenologies, habits, and origins. It was recognised that in any location $\times$ sowing date situation, only a small number of lines might be considered "adapted", and that the composition of this "adapted" group would change with location and sowing date.

Table 1 Mungbean and black gram genotypes grown in year-round sowings at five sites in Thailand

Mungbean :	Black gram :
1. Uthong 1	1. BC 48
2. UT 7808	2. Uthong 2
3. Phitsanulok White Pod	3. CPI 20143
4. Kamphaengsaen # 1	4. CPI 30067
5. VC 1178	5. Regur
6. King	6. DM 24
7. Berken	
8. Kiloga	
9. CPI 40704	
10. CPI 25070	
11. CPI 30757	
12. P 6712	
13. CPI 60823	
14. Golden Ball	

Cultural practices :

The aim of the cultural management at each site was to minimise specific environmental constraints not under study, whether soil related, biotic or climatic. Two replicated plots were sown at each site, sowing taking place into a finely cultivated and ridged seedbed. Individual genotypes were sown into 2 m long rows spaced at 1 m and using a hill spacing of 10 cm within rows. The seed was inoculated using a peat based rhizobium slurry. Irrigation was applied to assist establishment and again when necessary during dry periods, to minimise water stress. The number of seedlings was thinned to one per hill after establishment. Fertilizer as an N:P:K mix was applied at a rate of 18:54:36 kg. ha⁻¹ before each sowing. The pre-emergent herbicide Alachlor was combined with hand weeding for weed control. Insecticides were applied as required.

Daylengths (Figure 2) for each site were calculated by computer (Goodspeed, 1975). Daily maximum and minimum temperatures, rainfall, and where possible, radiation, were obtained from station meteorological facilities. Dates of sowing, emergence, flowering (50% of plants

with flowers), end of flowering and various pickings of mature pods, were recorded. Pods were picked at intervals as they ripened from the centre 1 m (10 plants) of each 2 m row. At each picking, numbers of pods and seeds were counted. At maturity, plants were cut, pods threshed, and all material dried and weighed; total plant weigh (TDM) and seed yield were recorded.

RESULTS AND DISCUSSION

For the purposes of this paper, only times to flowering and to first harvest are discussed. Further, at the time of writing, data and available for only the first six months of the study. These are however, sufficient to meet the objectives of this paper, to provide an overview of progress in this large, on-going study, and of its significance in terms of generating an understanding of the adaptation of mungbean and black gram in Thailand, and of some of the implications for crop improvement.

Climatic differences between sites :

Daylengths at the northern sites such as Phitsanulok and Khon Kaen are longer in June (and consequently shorter in December) than at the southern site of Hat Yai, the maximum difference being just over half an hour (Figure 2). Thus the seasonal variation in daylength at the northern-most sites was greater than at Hat Yai. The year-round variation at Hat Yai was only 50 minutes. Sites close together had only minimal daylength differences; between Phitsanulok and Khon Kaen the differences were only several minutes. Seasonal profiles of temperature and rainfall varied substantially between sites (data not shown). The period for which data are reported, May-November sowings, encompassed the wet, late-wet and early-dry seasons in the locations concerned. In the northern sites of Phitsanulok and Khon Kaen, minimum temperatures in November and December were of the order of 12–15°C, and the period between

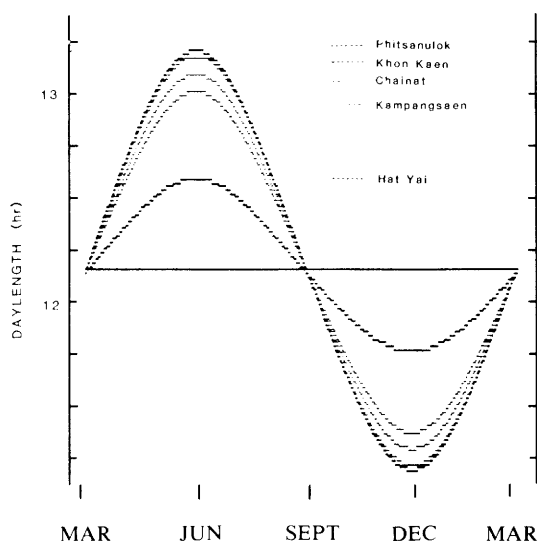


Figure 2 Daylength (including civil twilight) at five locations in Thailand.

Table 2 Variation in phenology of mungbean and black gram, with sowing date and location in Thailand.

(Data presented are for monthly sowings over the period May-November, 1986, at each of five sites; mungbean and black gram data are respectively means of 14 and 6 genotypes, expressed to the nearest half-unit).

(a) Days sowing to flowering :

	May	June	July	Aug.	Sept.	Oct.	Nov.	Site mean
Mungbean								
Phitsanulok	48.2	45.5	40.2	38.4	36.2	41.3	44.8	42.1
Khon Kaen	##	39.0	38.5	35.0	33.5	33.5	36.0	35.9
Chainat	42.5	42.0	39.5	37.5	35.0	35.0	**	38.5
Kamphaengsaen	##	39.9	36.3	33.8	28.5	32.0	30.6	33.5
Hat Yai	37.7	37.7	41.2	n.a.	37.5	39.9	n.a.	38.8
	42.8	40.8	39.1	36.2	34.1	36.3	37.1	37.8
Black gram								
Phitsanulok	62.9	57.0	42.5	37.8	37.2	39.3	48.3	46.4
Khon Kaen	##	46.5	40.0	36.5	31.0	32.0	32.0	36.2
Chainat	47.0	46.5	39.0	35.5	33.5	35.0	**	39.4
Kamphaengsaen	##	38.0	34.3	32.1	29.0	29.0	24.3	31.1
Hat Yai	35.9	33.3	36.5	n.a.	32.9	35.5	n.a.	34.8
	48.6	44.3	38.5	35.5	32.7	34.2	34.9	37.6

(b) Days to first pick :

	May	June	July	Aug.	Sept.	Oct.	Nov.	Site mean
Mungbean								
Phitsanulok	70.3	67.8	57.1	57.9	62.0	67.8	72.2	65.0
Khon Kaen	##	61.0	60.0	61.0	64.5	64.5	74.0	64.2
Chainat	77.0	80.5	64.5	63.0	63.0	64.0	**	68.6
Kamphaengsaen	##	63.4	59.6	58.5	51.5	62.3	66.5	60.3
Hat Yai ¹	—	—	—	—	—	—	—	—
	73.6	68.2	60.2	60.1	60.2	64.6	70.9	64.5
Black gram								
Phitsanulok	101.1	85.9	70.1	65.5	65.3	71.5	++	76.6
Khon Kaen	##	71.0	68.0	68.0	69.0	72.0	72.0	70.0
Chainat	125.0	104.0	94.0	85.0	84.5	74.0	**	94.4
Kamphaengsaen	##	72.0	66.0	69.0	60.0	66.3	60.8	65.7
Hat Yai ¹	—	—	—	—	—	—	—	—
	113.0	83.2	74.5	71.9	69.7	70.9	66.4	76.7

Sowings commenced in June at these sites

** Sowings not completed at time of preparation

n.a. data not available through crop failure

++ Flowers abscised without podset

¹ For Hat Yai, data for 1st pick is not included due to unreliability of results.

October-December was dry. In contrast, minimum temperatures in December at Hat Yai were 22–25°C, and, as is usual for Southern Thailand, rainfall continued until December. Only the latest sowing at Hat Yai matured into the dry season.

Effects of location and sowing date :

Means for times-to-flowering and to maturity are summarised for the various locations and sowing dates in Table 2. In the case of mungbean, mean time-to-flowering was reduced by about 20% as sowing was delayed progressively from mid-year to September. For sowings thereafter, time-to-flowering increased. Among locations, time-to-flowering was longest at Phitsanulok, the most northern site. On average, however, differences between locations in time-to-flowering were generally small. In the case of black gram, sowing date and location effects were more pronounced. Mean time-to-flower was reduced by a third as sowing was delayed from May until September. Among locations, time-to-flowering was longest at the three northern sites, and shortest at the two most southern sites. Differences among locations were greatest at the earlier (rainy season) sowings and least for sowings in September-October. In the earlier sowings, time-to-flowering was generally shortest at Hat Yai, the most southernly site, and longest at Phitsanulok, Khon Kaen and Chainat. Interestingly, for both mungbean and black gram, time-to-flowering was generally longer at Phitsanulok than at Khon Kaen, although the two are at similar latitude (Figure 1).

Differences between locations and sowing dates in terms of time-to-first-pick generally reflected those in time-to-flowering (Table 2), with the exception that the time-to-first-pick was shortest in the August sowing for mungbean, and the September sowing for black gram. Thereafter, time-to-maturity increased again, a trend which became most pronounced at the northern sites. As with time-to-flowering,

differences between locations and sowing dates in the time-to-first-pick were substantially greater in black gram than mungbean. Again, differences between location were most pronounced in the earlier sowings. For example, mean time-to-first-pick in black gram was substantially shorter at Kamphaengsaen than the more northerly sites in July and September sowings.

Genotypic differences :

There were large differences between genotypes in terms of response to sowing dates, locations, and sowing dates within locations. In general, differences among genotypes in times-to-flowering and time-to-first-pick were greatest at the earlier sowing dates, and at the more northernly sites. Conversely, all lines tended to be earlier flowering and similar at Hat Yai, and for sowings after August. Thus, in effect, the dispersion among genotypes was greatest for wet-season sowings, and at the northern sites.

The nature and magnitude of the differential genotypic responses to location and sowing date are exemplified by the following comparisons of two genotypes from each crop. In the case of mungbean, the extremes of response are characterised by VC 1178, an early-maturing line from AVRDC, and CPI 60823, a late-maturing line (Baisakhi Mung), originally from India (Imrie *et al.*, 1981 a). In the present experiment, VC 1178 flowered, on average, a month after sowing (Table 3) and the first-pick was made on average, around two months from sowing. By way of comparison, CPI 60823 flowered on average almost two months after sowing, and the first-pick was, on average, around three months from sowing. For black gram, the extremes of response are illustrated by DM 24 and CPI 30067. The former is an early-flowering breeding line from Australia (R.J. Lawn, unpubl.) and the latter, a late-maturing line (NP 4), originally from India (Imrie *et al.*, 1981 a). In this study, DM 24 flowered, on average, slightly more than a month

Table 3 Variation in phenology of two contrasting mungbean genotypes with sowing date and location in Thailand.

(Data presented are for monthly sowings over the period May – November, 1986, at each of five sites)

(a) Days sowing to flowering :

	May	June	July	Aug.	Sept.	Oct.	Nov.	Site mean
VC 1178								
Phitsanulok	36.5	31.5	31.5	31.5	31.0	39.0	41.0	34.6
Khon Kaen	# #	26.0	31.0	26.0	27.0	28.0	32.0	28.3
Chainat	28.0	31.0	32.0	30.0	30.0	30.0	**	30.2
Kamphaengsaen	# #	34.0	28.0	22.0	23.0	24.0	23.0	25.7
Hat Yai	24.0	30.0	33.0	n.a.	31.0	33.0	n.a.	31.8
	29.5	30.5	31.1	27.4	28.4	30.8	32.0	30.1
CPI 60823								
Phitsanulok	83.5	85.5	45.0	47.5	41.0	40.0	43.5	55.1
Khon Kaen	# #	93.0	72.0	58.0	42.0	34.0	30.0	54.8
Chainat	102.0	90.0	67.0	57.0	39.0	37.0	**	65.3
Kamphaengsaen	# #	77.0	32.0	50.0	40.0	28.0	26.0	42.2
Hat Yai	57.0	50.0	61.0	n.a.	50.0	52.0	n.a.	54.0
	80.8	79.1	55.4	53.1	42.4	38.2	33.2	54.3

(b) Days to first pick :

	May	June	July	Aug.	Sept.	Oct.	Nov.	Site mean
VC 1178								
Phitsanulok	60.0	53.0	51.0	54.0	62.0	67.0	71.0	59.7
Khon Kaen	# #	49.0	51.0	48.0	60.0	66.0	72.0	57.7
Chainat	52.0	58.0	57.0	56.0	57.0	59.0	**	56.5
Kamphaengsaen	# #	57.0	43.0	64.0	47.0	89.0	88.0	64.7
Hat Yai ¹	—	—	—	—	—	—	—	—
	56.0	54.2	50.5	55.5	56.5	70.2	77.0	59.6
CPI 60823								
Phitsanulok	115.0	106.0	56.5	68.0	62.0	70.0	72.5	78.6
Khon Kaen	# #	116.0	110.0	90.0	76.0	65.0	71.0	88.0
Chainat	146.0	135.0	106.0	85.0	74.0	66.0	**	102.0
Kamphaengsaen	# #	92.0	87.0	76.0	61.0	64.0	69.0	74.8
Hat Yai ¹	—	—	—	—	—	—	—	—
	130.5	112.2	89.9	79.7	68.2	66.3	70.8	85.8

Sowings commenced in June at these sites

** Sowings not completed at time of preparation

n.a. data not available through crop failure

1 For Hat Yai, data for 1st pick is not included due to unreliability of results.

Table 4 Variation in phenology of two contrasting black gram genotypes with sowing data and location in Thailand.

(Data presented are for monthly sowings over the period May – November, 1986 at each of five sites)

(a) Days sowing to flowering :

	May	June	July	Aug.	Sept.	Oct.	Nov.	Site mean
DM 24								
Phitsanulok	39.5	37.0	37.5	34.5	33.0	37.5	49.5	38.4
Khon Kaen	# #	27.0	32.0	32.0	29.0	29.0	33.0	30.3
Chainat	33.0	34.0	34.0	31.0	31.0	31.0	**	32.3
Kamphaengsaen	# #	30.0	30.0	37.0	27.0	30.0	31.0	30.8
Hat Yai	33.0	31.0	33.0	n.a.	31.0	33.0	n.a.	32.2
	35.2	31.8	33.3	33.6	30.2	32.1	37.8	32.8
CPI 30067								
Phitsanulok	108.0	80.0	46.5	34.0	30.0	36.0	40.5	53.6
Khon Kaen	# #	84.0	52.0	35.0	28.0	26.0	29.0	42.3
Chainat	82.0	66.0	41.0	34.0	29.0	28.0	**	46.7
Kamphaengsaen	# #	52.0	35.0	22.0	21.0	24.0	25.0	29.8
Hat Yai	38.0	30.0	35.0	n.a.	31.0	32.0	n.a.	33.2
	76.0	62.4	41.9	31.2	27.8	29.2	31.5	41.1

(b) Days to first pick :

	May	June	July	Aug.	Sept.	Oct.	Nov.	Site mean
DM 24								
Phitsanulok	80.0	70.0	64.0	63.0	62.0	70.0	88.0	71.0
Khon Kaen	# #	48.0	57.0	60.0	59.0	63.0	74.0	60.2
Chainat	121.0	93.0	83.0	77.0	91.0	74.0	**	89.8
Kamphaengsaen	# #	59.0	55.0	66.0	63.0	81.0	70.0	65.7
Hat Yai ¹	—	—	—	—	—	—	—	—
	100.5	67.5	64.7	66.5	68.7	72.0	77.3	71.7
CPI 30067								
Phitsanulok	136.0	106.0	76.0	63.0	62.0	70.0	+ +	85.5
Khon Kaen	# #	113.0	97.0	82.0	60.0	64.0	72.0	81.3
Chainat	151.0	123.0	106.0	80.0	60.0	68.0	**	98.2
Kamphaengsaen	# #	96.0	96.0	64.0	52.0	81.0	70.0	76.5
Hat Yai ¹	—	—	—	—	—	—	—	—
	143.5	109.5	93.7	72.2	58.5	70.7	71.0	85.4

Sowings commenced in June at these sites

** Sowings not completed at time of preparation

n.a. data not available through crop failure

+ + Flowers abscised without podset

1 For Hat Yai, data for 1st pick is not included due to unreliability of results.

after sowing, compared with an average six weeks for CPI 30067 (Table 4).

In general, VC 1178 showed substantially smaller variation in phenology over sowing dates and locations than CPI 60823 (Table 3). The range in time-to-flowering for VC 1178 across all location $\times$ sowing date combinations was 22–41 days, compared with 26–102 days for CPI 60823. Likewise, for black gram (Table 4), where the range in times to flowering for DM 24 was 24–50 days, for CPI 30067 it was 21–108 days. In general, the patterns were similar for comparisons of times-to-first-pick (Table 3, 4).

In both species, the respective patterns of variation in phenology over locations and sowing dates were generally similar, although somewhat more pronounced in black gram. Flowering in the environmentally least-sensitive lines, VC 1178 and DM 24, was shortest in August or September sowings, with only small differences, on average, between locations. In contrast, flowering in the two sensitive lines, CPI 60823 and CPI 30067 was substantially longer in the May sowing, and declined progressively as sowing was delayed to September (CPI 30067) or November (CPI 60823). Interestingly, in the November sowing, flowering occurred as soon in the late mungbean, CPI 60823, as in the early line VC 1178. And in black gram, CPI 30067 actually flowered before DM 24 for sowings after July.

Among locations, flowering of the sensitive lines occurred most rapidly at the two most southern sites, Hat Yai and Kamphaengsaen. Again, patterns of response in time-to-first-pick reflected those in time-to-flowering. An exception was that time-to-first-pick tended to increase for sowings after August-September, particularly in the early-flowering lines. Contribution of photothermal regime to regional/seasonal effects:

The patterns of response described above can be explained in terms of differential genotypic sensitivities to the variation in daylength and temperature over these locations and sowing

dates. In the case of the most environmentally-responsive genotypes, CPI 60823 and CPI 30067, the situations where flowering was delayed corresponded to where days were longest i.e. the most northerly sites, and sowings in May-June (cf. Figure 2, Tables 3, 4). At lower latitude (Hat Yai) and later sowings (September-November), daylengths were progressively shorter and flowering occurred sooner. This response is consistent with quantitative short-day photoperiodic response.

In the case of the least-responsive lines, VC 1178 and DM 24, there was no evidence that flowering was delayed by long-days, and their response is therefore consistent with daylength-insensitivity, at least for the range of daylengths experienced at these five locations in Thailand. It is possible, however, that tests at higher latitudes, where daylengths are longer, might show either or both lines to be daylength-sensitive. And, given that temperature can affect critical daylength (Roberts and Summerfield, 1987), it is possible that either or both lines could show daylength sensitivity in locations combining cool temperature-longer day conditions e.g. in the highlands. This hypothesis remains to be tested.

It is probable, given the wide range of daylengths and the comparatively narrow range of (relatively warm) temperatures for the period of the study reported, that in the photoperiod-sensitive lines, effects of temperature were partly masked by the pronounced effects of daylength. Nonetheless, there was evidence of temperature effects, particularly with the later sowings, where cooler temperatures tended to slow rates of development. This effect was most pronounced for the sowings of VC 1178 and DM 24 made after August. Although the later sowings still flowered rapidly, subsequent development occurred during the cooler months, so that the time to first pick was progressively delayed (Table 3, 4). These effects tended to be masked in CPI 60823 and CPI 30067 by the progressive

reduction in time to flowering in response to the shorter days.

It is probable that much of the variation over sites and sowing dates in time-to-flowering in VC 1178 and DM 24 occurred in response to variation in temperature. Confirmation of this will depend on the development of quantitative relationships between rates of development towards flowering and the two key climatic variables. The various parameter estimates derived from such quantitative relationships should provide valuable information concerning the nature of the flowering response to photo-thermal regime, and its sensitivity to change in both daylength and temperature. In turn, this information can be used to predict flowering response in particular environments not tested in the present studies. Alternatively, the nature of the differences among genotypes can be defined more clearly, so that genetic manipulation of the differences is facilitated.

Implications for mungbean and black gram improvement :

It is clear that for even the comparatively narrow range of latitudes encompassed in Thailand, and the range of sowing dates between May-November, the magnitude of environmental effects on phenology of mungbean and black gram is potentially large. Further, the potential magnitude of genotype $\times$ environment interaction is also large. This poses difficulties in breeding genotypes which are simultaneously adapted to the broad range of environments in which the two crops might be grown. The task is even more complex when it is considered that genotypes may show differential sensitivities to environmental factors between different phenological stages. However, for various reasons, it would be desirable to breed cultivars which could be used throughout the seasons at any location, and over as wide a region as possible.

At one extreme, genotypes of both mungbean and black gram were identified in

which seasonal and regional effects on time-to-flowering were relatively small. However, in both cases supplemental data on plant growth and yield suggest that flowering occurred too soon after sowing, so that in most situations there would have been inadequate vegetative growth to ensure high yield potential, even at a high sowing density. What is needed are alternative genotypes with similar or better stability of response, but which are later-flowering. At the other extreme, lines were identified which, in the more northerly sites, were late-flowering and excessively vegetative. As such, their adaptation is restricted, in phenological terms, to either the most southern, tropical locations or alternatively, to late rainy season or dry season sowings. It should be recognized however that a restricted range of adaptation may not, of itself, be sufficient reason to discard high-yielding genotypes from use within their range of adaptation.

The four accessions described in detail in this paper, represent extremes of flowering response encountered in the 14 mungbean and 6 black gram genotypes tested. Most other genotypes revealed intermediate patterns of response. As such, it is likely that a detailed quantitative analyses of their responses will show that they arise as a consequence of various combinations of sensitivities to either or both daylength and temperature. It is from this intermediate group of germplasm that breeders will draw most in the foreseeable future. A detailed knowledge of the nature and extent of the differential sensitivities to daylength and temperature within this material should assist them in their task.

ACKNOWLEDGEMENTS

The research reported in this paper was supported by the Australian Center for International Agricultural Research (ACIAR). Acknowledgement is expressed for the contributions of Dr. Vichitr Benjasil, Mr. Nark Potan,

Mr. Somyot Pichitporn, and Mrs. Kanokport Maolanont of the Field Crops Research Institute in the Department of Agriculture; also to Dr. Sawai Pongkao and Ms. Harisadee Patharadilok of Kasetsart University, and Dr. Anake Topark-Ngarm and Ms. Sutthinee Intarakhamhaeng of Khon Kaen University.

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